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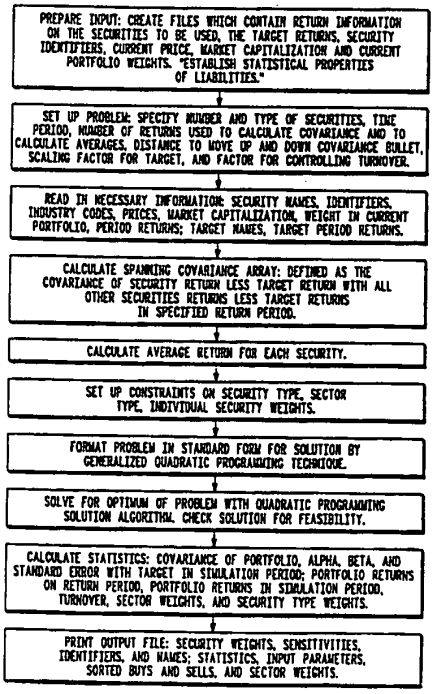

(57) Abstract

A method and system for correlating an expected asset return of a portfolio to changes in future financial liabilities and also to other financial indices. Management of asset portfolios often requires precise matching of liability streams, such as is the insurance industry and for pension funds. The method selects the weight percentages of assets by achieving optimum statistical correlation between asset returns and liability returns.

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RAPID METHOD OF ANALYSIS FOR CORRELATION OF ASSET RETURN TO FUTURE FINANCIAL LIABILITIES

The present invention is related generally to a method and system for selecting a portfolio of assets for achieving optimum correlation of asset return to a selected standard financial index. More particularly, the invention is related to a highly efficient, rapid method and system for choosing an asset portfolio having the optimum correlation of the asset return to a time dependent financial index, such as a financial liability, at each of a number of selectable asset return levels.

Management of portfolios of assets has historically emphasized maximizing the return on assets with the objective of at least outperforming the market. However, in some financial industries the objective, or the figure of merit, is also related to meeting future liabilities rather than just achieving high return on assets. Frequently, an institution will have a future intended use of the assets which requires their availability at some future time. If assets are performing differently than liability requirements, substantial financial hardship can result. For example, insurance companies and corporate pension plans have well defined future financial liabilities which must be met. Consequently, although return on assets is one important objective, meeting future liabilities is also important and can be even more

important in many instances. In fact, many pension plan managers are now required to meet the standards set forth in FASB Statement 87 (Financial Accounting Standards Board) on pension fund accounting. Under the FASB Statement a market interest rate return on pension funds is the standard index and is to be based on A-rated ten year corporate bonds. Under this FASB Statement any deficit in corporate pension funds are now reflected on the balance sheet. Any such deficit would therefore have substantial adverse effect on the apparent net worth of the subject corporation. Consequently, this FASB Statement standard strongly encourages maintenance of a surplus for a pension fund. As an example of the importance of matching the liability requirements under the FASB Statement, consider the percentage change possible for pension plan liabilities, as measured by the accumulated benefit obligation (ABO). If, for example, interest rates increase by 1% in one year over the present rates, the present value of the ABO would decline by 10% if the ABO has a duration of 10 years. Likewise, if interest rates were to drop by 1% in one year, the present value of the ABO would increase by 10%. The potential for such dramatic fluctuations in liabilities clearly deserves careful attention by parties obligated to meet future liability streams.

In order to timely meet future financial liabilities and maintain a proper surplus fund for a pension plan, a number

of methodologies have arisen including "immunization", "cash matching"; and some preliminary efforts have even been directed to utilizing stock funds.

The "immunization" method of meeting future financial liabilities uses bonds having substantially the same duration as the liability stream. Duration is a measure of volatility expressed in years, which is similar to, but more precise than, average life. The duration is calculated as the weighted average amount of time to the receipt of the payout. There are however significant drawbacks to "immunization", with one primary disadvantage being the relatively low excess return on assets generally achieved by the method. Additional limitations are imposed by the two major assumptions made by the strategy: The yield curve (a plot of yield to maturity on bonds versus their time to maturity) will only make parallel shifts. Consequently, regardless of maturity, when market conditions change, all bonds allegedly move exactly the same amount in yield. This clearly is not the case since there have been substantial inconsistencies in the past for the difference in rates for short-term bonds and long-term bonds. Secondly, all cash flows in excess of required annual payments can allegedly be reinvested at the yield to maturity of the portfolio. This presumption is also clearly not true since sharply declining or rising interest rate environments will make it extremely difficult to carry out reinvestment.

Furthermore, this strategy does require more ongoing management of the portfolio in order to sell or buy more securities to match the actuarial schedule and maintain a proper asset/liability match.

The "cash matching" method utilizes a bond portfolio having numerous component bonds with various maturity dates and payout rates to precisely match the liability requirements of the pension plan. Such an approach has the same primary disadvantage as the "immunization" method and further requires additional effort to assemble the portfolio. Frequently, the "cash matching" method demands payment of a premium to achieve the correct mix of bond rates and maturity. Both of the first strategies ("immunization" and "cash matching") must invest in fixed income securities to provide the assurance of receiving the necessary cash flows. In fact, they must primarily invest in U.S. treasury obligations since investments in corporate or mortgage securities increase the chance for default or for call risks which can have the effect of changing the projected cash flow.

Pension plan liabilities or other future liabilities, such as are present in the insurance industry, are long term in nature. Therefore, a future liability stream can greatly benefit from the compounding effect of investment in higher returning assets, such as common stocks. However, attempts to characterize stocks in terms of a time duration parameter or

otherwise have not been successful. In the last few years many unsuccessful attempts have been made to develop a system whereby a portfolio of equities is linearly optimized relative to a liability stream. There have been attempts to parallel the "cash matching" techniques with the use of stocks, instead of bonds. This approach has involved matching the expected dividend flow of the portfolio to the liability stream. Unfortunately, stock dividend yields are unpredictable, particularly beyond 3 years in the future. Another major effort in equities has been directed to an "immunization" type treatment. In this effort an attempt was made to calculate the duration of stocks on an individual basis, as well as on a portfolio basis; but these attempts also have been unsuccessful, primarily due to the long term unpredictability of stock dividends.

In a related patent application, incorporated by reference herein and having serial number 281,560 and filed December 8, 1988, an improved method and system were set forth directed to correlating return on assets to a financial objective over time. In performing the analysis to determine the optimum assets of a portfolio to track the financial objective, the machine time and efficiency of the evaluation process can limit the number of assets considered in constructing the portfolio. Such limitations on the number of assets which are considered for inclusion in the optimum

portfolio can also limit the performance of the selected portfolio.

It is therefore an object of the invention to provide an improved method and system for determining the optimum portfolio of assets for tracking a financial index.

It is another object of the invention to provide a new method and system of efficiently selecting the optimum portfolio of assets for tracking a financial index.

It is an additional object of the invention to provide an improved method and system of rapidly analyzing a large number of potential assets to select the optimum portfolio of assets to track a financial index.

It is a further object to provide a new method and system of enlarging the number of potential assets under consideration for inclusion in a portfolio of assets, while reducing the time required to select the portfolio of assets which best track the behavior of a financial index.

It is another object of the invention to provide a rapid, more efficient method and system of selecting the weighted values for assets selected from a universe of possible assets for a portfolio designed to track a financial index.

It is an additional object of the invention to provide an improved method and system for reinvesting cash flow from a portfolio starting with that current portfolio of assets.

Further objects and advantages of the present invention, together with the organization and manner of operation thereof, will become apparent from the following description when taken in conjunction with the accompanying drawings described hereinbelow.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1A is a functional flow chart illustrating operation of one method of portfolio construction and FIG. 1B is a flow chart illustrating operation of a particular method of the invention;

FIGURE 2A illustrates simulation results of annual total liability returns of a pension plan (dashed) and annual total asset returns (solid line) for a preferred form of the invention and FIG. 2B shows annual total liability returns of the simulated pension plan (dashed) and annual total asset returns (solid line) for the Standard & Poors 500;

FIGURE 3A is a bar graph of simulation results for funded status returns over time for a preferred method of the invention and FIGURE 3B is a bar graph of funded status returns over time for the Standard & Poors 500;

FIGURE 4 a comparative plot of cumulative funding status for simulation results over time for a pension plan liabilities (dashed), a portfolio derived by a preferred method of the invention (solid line) and the Standard & Poors 500 index (dashed and dotted);

FIGURE 5A shows the correlation between asset return and liability return for a preferred method of the invention and FIG. 5B illustrates correlation between asset return and liability return for the Standard & Poors 500 index; and

FIGURE 6 illustrates the boundary line of minimum risk for various future asset return levels.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Broadly stated, a method and system are described for selecting a portfolio of assets and correlating a future asset return of the portfolio to a financial index, such as, a liability index, an inflation index, or any other accepted index and mixtures thereof. Specific examples of indices are liability indices, such as, individual corporate pension plan liabilities and insurance company liabilities. The consumer price index and wage growth index are examples of an inflation index, and other indices can include accepted stock price indices and futures markets indices. The method includes selecting asset portfolios which optimally correlate portfolio returns to the future desired payouts or payments needed over time to fulfill the desired financial objective. In the general case the user selects a standard index to which optimum correlation is desired for the selected portfolio having a future asset return over time. The process of selecting the

standard index can involve obtaining input (such as actuarial) in terms of the characteristics of future cash payments discounted to present value based on a range of discount rate and wage (inflation) values. This information can be used to construct a functional behavior for the present value of the liability. A decision is then made, such as by a company pension fund manager, that certain discount rates and inflation assumptions should be made. On this basis the current liabilities are projected back in time using these assumptions and a plurality of assets are examined to determine their sensitivity to the past behavior of the liability returns. In the most general sense if one can determine an index to which a portfolio of assets has a strong correlation, this sensitivity can be used to select a set of assets which will match the behavior of the index as it changes over time. As a particular example an actuary can provide specific ranges of present value liability for a range of discount rates and inflation rates. The change over time of the liability from month to month over a twenty four month period can yield a liability return. The analysis to be described in more detail hereinafter determines which selected ones of a plurality of assets track the liability returns with best correlation. The resulting weighted set of assets form the portfolio to follow the future liability returns. An analysis using the selected standard index can be performed on a plurality of assets, such as, for

example, at least one of the following categories of assets: stock securities, real estate investments, futures contracts, options, commodities, currencies and precious metals. The analysis allows the identification of the combination of weight percentages of selected ones of the plurality of assets yielding the optimum correlation of the future asset return to the standard index. Optimum correlation is thus achieved by calculating a minimum standard deviation or a variance for the difference between the return of the portfolio of assets and the selected standard index return. This method and system are particularly applicable for, but not limited to, the insurance industry and management of pension fund liabilities.

FIGS. 1A and 1B illustrate in functional flow charts the procedures followed in carrying out two forms of the invention. In the first method shown in FIG. 1A (and described previously in pending application having serial number 281,560) the correlation of the expected asset return of a portfolio to a standard index one is initiated by input of various basic information. This information includes, for example, establishing the fundamental statistical characteristics of liability returns, and future payment schedules for matching a desired index, such as the future stream of financial liabilities of a pension plan. As described hereinbefore, the future payment schedule for a pension plan can be determined by using actuarial data. These future liabilities can be

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characterized in terms of an accumulated benefit obligation (ABO), that is, the price you would have to pay if the liabilities were sold at a selected time. The total outlay required to pay retirement wages for the pension plan are discounted back to the present value at the market rate interest (currently 10%). Other related characterizations can be used, such as a projected benefit obligation (PBO), by accounting for inflation in the growth of wages at retirement. This amount is converted to a percentage and an expected salary at retirement, discounted to present value. Therefore, although the ABO is affected primarily by interest rates, additional standard measures, such as the PBO, account for inflation. Therefore, the method is also generally effective for calculating the convolution of complex effects with one another. The method only requires optimizing correlation of the time behavioral performance of future asset return relative to the particular standard index, which includes any conceivable selected characteristic which assets are found to be sensitive to.

In the manner illustrated in step 1 of FIG. 1A, various input files are therefore created to begin the analysis. These input files can include, for example, asset return information for the universe or plurality of assets to be sampled in the analysis. Also established as data files are the data representative of the standard asset return over time,

such as target returns for a future liability stream of a pension plan or an insurance company. The future liability stream can depend on interest rates and/or inflation rates and other variables which can affect the liability stream. For example, as described hereinbefore, a surface can be generated which describes the behavior of liability return as a function of both interest rates and inflation rates. Other information in the data files can be identification information for the plurality of assets, current price and market capitalization of the assets, as well as the characteristic weight percentages of assets in a previously selected portfolio. Weight percentages, for example, from a prior period would be used in the most preferred embodiment.

As illustrated in the second box of FIG. 1A, the number and type of the plurality of assets should be specified, the time period for matching the standard, the number of returns used to calculate a statistical correlation and the number of asset returns used to calculate averages for the plurality of securities to be analyzed to select the optimum set of weighted assets.

The method in FIG. 1A then initializes information preparatory to analyzing the plurality of assets, such as, establishing names of securities, associated identifier information, industry codes, prices of securities, market capitalization, weight and percent of the previously calculated

prior portfolio, the period for the asset return, the name of the target or standard for measuring a standard asset return and the time period for the standard returns.

In the next box in FIG. 1A the correlation between the future asset return and the standard index is optimized by first generating a covariance array. While other nonlinear statistical analyses are possible, this method being described is a preferred method of carrying out the analysis. For example, another useful statistical method of analysis is correlation parameterization which is embodied in the computer software program Appendix III. As shown in the next step in FIG. 1A, the average return of each security is calculated followed by imposing certain constraints on the calculation, such as setting a range of weight percentages to be tried. The calculation is then implemented to a solution by a standard computer program quadratic technique (see Appendix I). This step is then followed by determination of various statistical parameters, such as X and B, standard error, portfolio returns over various time periods and for selected weights. The analysis is then completed by printing output (see attachment to Appendix I) such as asset weights, sensitivity factors for selected assets of the portfolio, statistical parameters, sorted buy and sell orders and sector weights.

A simple example of utilizing the preferred statistical method is illustrated for a portfolio containing

three stocks (designated 1, 2, and 3). In order to find the optimum weight percent for each of the three stocks in the portfolio, the minimum standard deviation (square root of variance) is calculated for the differences between the assets of the portfolio and the future liabilities as represented by the standard asset return over time. The risk is therefore defined as the standard deviation of differences:

$$\text{Risk} = \frac{\left[\sum_{i=1}^{n} (R_{pi} \; R_T \; i) - n \; R_p \; R_t\right]^{1/2}}{(n-1)^{1/2}} = \sigma[R_p - R_t] = \text{variance}^{1/2}$$

where: R_{pi} = total return on the portfolio during period i;

R_{Ti} = total return on target or standard in period i,

σ = standard deviation;

R_p = average return on portfolio, i = 1,n; and

R_T = average return on target or standard portfolio of assets,

i = 1,..., n...

The portfolio return equals percentage weight for each stock times the return on that stock:

$$R_{pi} = \sum_{j=1}^{3} x_j R_{sj,\,i}$$

x_j = the weight in the portfolio of the stock j

$R_{sj,i}$ = the return on stock j in periods i

Now in the definition of risk, as set forth above, we can substitute the following:

$$R_{pi} = \sum_{j=1}^{3} x_j \; R_{sj,\,i}$$

Making this substitution, a determination of risk in the manner set forth above results in the calculation of the covariance of the stock with each of the other stocks in the portfolio after subtracting the return of the target, or standard index, from the future asset return of each stock.

The covariance of stock 1 with stock 2 is therefore:

$$(R_1, R_2) = \sum_{i=1}^{n} (R_{s1i} - R_{Ti})(R_{s2i} - R_{Ti}) - n\,(\hat{R}_1 - \hat{R}_T)(\hat{R}_2 - \hat{R}_T)$$

We calculate all the spanning covariances and put them in a matrix form:

$$\begin{bmatrix} \text{Cov}[(R_1 - R_T), (R_1 - R_T)] & \text{Cov}[(R_1 - R_T), (R_s - R_T)] \\ \text{Cov}[(R_3 - R_T), (R_1 - R_T)] & \text{Cov}[(R_3 - R_T), (R_3 - R_T)] \end{bmatrix}$$

In order to calculate the risk, we add up all the Cov terms times the weights in each stock:

$$\text{Risk} = \sigma(R_p - R_T) = \left\{ \left[\sum_{i=1}^{3} \sum_{j=1}^{3} X_i X_j \text{Cov}[(R_i - R_T), (R_j - R_T)] \right] \right\}^{1/2}$$

In order to minimize this "risk" function, we determine the combination of weight percentages for stocks 1 thru 3 which produces the smallest statistical risk. The above described risk can readily be calculated by various means, such

as, by a computer program (which is included in Appendix I). The output (see attachment to Appendix I) of the calculation includes the weight percent of each stock and the associated overall risk level. This calculation can be repeated for a range of expected asset return levels and results in generating a nonlinear type "bullet" shape defining the limits of minimum risk over a range of asset return levels for associated standard deviations of funding level (see FIG. 6). The method uses historical returns for the plurality of stocks analyzed in order to calculate the resulting covariance between the standard liability returns and the future returns of the potential portfolio of assets. Appendix II illustrates an example of a computer program for calculating typical liability return data. The method of analysis results in choosing a selected set of assets for the portfolio with a strong inclination of the selected set of assets to respond in a manner such as the standard asset returns over time, which alone can be valuable output. As mentioned hereinbefore, in other embodiments, the nonlinear analysis of a plurality of assets can involve other methods, such as, index correlation parametrization for matching the performance of a target index return (see Appendix III).

In one embodiment of the invention illustrated in FIG. 1B, the method is a simplification of the more formal procedure of FIG. 1A. The method of FIG. 1B accomplishes,

however, the same result as in FIG. 1A but with much greater efficiency and speed.

The method of FIG. 1B is broken into eleven steps, and the first three steps are substantially the same as the method of FIG. 1A. The eleven steps and details of each each step are described below:

I. Read in Returns of Selected Securities. Large numbers (thousands of securities) can be utilized in this procedure. An input file contains the returns for each security in the prior periods, such as the previous 24 months. Various data is included, such as, security name, industry groups code, market capitalization, trading volume, recent prices, specific identifiers and estimated bid/ask price spreads. The effect of transaction costs associated with the spread in the bid/ask price can be included in the performance analysis.

II. Read in Returns of Target Index to Track. If a portfolio is to be constructed for tracking a specific financial target index, the returns to that target for the relevant period are read into memory arrays. Additional identifying information is also read in from the target data file.

III. Set-up Constraints on Upper and Lower Bounds in Terms of Percent of Portfolio for each Security and each Sector or Industry. A maximum and minimum percentage weight of

the portfolio for each security can be specified to constrain the portfolio. This can be used to insure portfolio diversification and to control costs associated with trading. In addition, sectors of the universe, for example, utility stock, can be constrained by maximum and minimum boundaries. If one has a single target, one can "short" a stock and take a negative minimum position.

IV. Calculate the Covariance of Each Security with the Target Index. If a target is used the covariance is calculated for each security and stored in an array. If no target index is used, a zero value for each security is stored in the array.

V. Create an Initial Portfolio by Selecting Highest Covariance Securities and Weighting Them at their Upper Limits as Defined by Selected Constraints. This step creates an initial feasible solution to the problem by filling the vector of portfolio weights according to the constraints and in order of highest covariance.

VI. Calculate the Objective Function Value at Initial Portfolio Weightings. The objective function can be defined in a number of ways. The computer program allows monthly or moving quarterly returns to be used for optimization. Transaction costs can be considered and their importance magnified or reduced relative to other objectives. With minor changes, other such goals can be incorporated into

the objective function. The key is that once the objective function is specified, partial derivatives can be used to guide the search for an optimal portfolio. Any example of a preference that can be created is an increased weighting for a stock with a likely dividend versus one with no dividend.

VII. Calculate Partial Derivatives for Each Security at Initial Portfolio Weightings. A partial derivative is calculated for each variable (in this case each security), and a direction can be determined in which to move the individual security weights in order to obtain an improved portfolio solution. The partial derivatives are also used to determine if the weights are optimal. In the prior art, the solution techniques require storage of a full covariance matrix array. This storage requirement has limited the practical number of securities which could be considered at one time in the past methodologies. Indeed, the storage requirements, and to a large degree the processing time, varies as the square of the number of securities in the portfolio under consideration. See the example discussed hereinafter in which the previous methodology is compared to the invention.

In addition, the methods of solution for these problems in the prior art were slow and cumbersome and subject to failure when the full covariance array was sensitive or a nonunique set of solutions were achievable. This current method requires much less storage, uses a rapid solution

technique and allows control of the tolerance used for optimality. Consequently, the improved methods will select a portfolio when several combinations are equally desirable.

Not only is the amount of necessary memory reduced and the computer calculational time greatly reduced, there is substantial flexibility in defining the objective, assurance of the solution is enhanced and simultaneous considerations of large number of securities allows substantial improvement in optimizing the expected return of the portfolio compared to the target index.

VIII. Change of Portfolio Weightings by Moving in Direction of Improvement is Indicated by Partial Derivatives. Adjustment of the portfolio weights is achieved by a search technique which moves along the constraints and changes in a proper direction of improvement of the objective function. The objective function is calculated at the new weights and a test of improvement is made.

IX. Test for Convergence to an Optimal Solution Defined by the Kuhn-Tucker Conditions. If the objective function is not improving or if the step size used to adjust the portfolio weights becomes extremely small, the search is terminated. This solution is normally a Kuhn-Tucker point (conventional method of establishing optimality conditions) or extremely close thereto within an acceptable epsilon to such a point.

X. Recycling Conditions. If the termination conditions are not satisfied then one re-calculates the objective function value, re-calculates the partial derivatives, makes changes in the portfolio weightings to achieve an improved solution and test for convergence.

The process is by nature iterative and continues cycling until a solution is reached in which diminishing returns are achieved by further cycling.

XI. Output of Information. Relevant portfolio information is output with security weightings, objective function values, purchases and sales necessary to achieve the optimum portfolio and industry weightings.

The detailed output is written into a computer file which then can be examined for relevant information. Order to buy and sell securities can be developed from the information in the output file.

Included in Appendix IV is an exemplary computer software (source output) program illustrating critical steps of the method of FIG. 1B. Table XI shows exemplary results for a program simulation wherein the target index is the Standard and Poors 500 stock index. Appendix VI illustrates significant distinctions from the optimizer methodology used in the copending patent application having serial number 281,560.

Quantifying Magnitude of Reduced Computation Time

A test was performed on an IBM compatible PC to

compare the solution speeds of two portfolio optimization systems. In a prior system, the problem of handling large numbers of securities in a portfolio selection process increased in proportion to the number of securities squared. Thus, a problem involving one hundred securities would take approximately one hundred times as many calculations to solve as a problem with ten securities.

In the current system the solution difficulty increases by a factor of less than one times the number of securities. In addition, the computing memory required to solve the problem is proportional to the number of securities rather than, as in the prior system, that number squared.

Solution Time Comparison:

Hardware: IMB compatible PC, 386-20Mhz CPU, 80387 co-processor

Problem Size: 100 securities

3% portfolio weight upper bound on each security

0% portfolio weight lower bound on each security

Time to solution:

Prior system - 9 minutes 34 seconds

Current system - 52 seconds

Overall speed-up: 11.0 x prior system

This speed increase is actually of a larger magnitude since approximately 40% of the 52 seconds to solution with the current system is spent reading information from external files and writing information to other files. The solution time speed-up, allowing for reading and writing files, is approximately 17.3 x prior system. This speed-up ratio increases in proporation to the number of securities considered squared.

The speed increase and the reduced computer memory requirements by the current system allow large problems to be solved in a short time, requires limited computer memory, and uses computer hardware which is relatively inexpensive.

Circumstances arise regularly in the investment field which rapidly change the prospects for securities. The impact of these sudden changes must be incorporated into the security valuation system so that rational alternations in the investment portfolios may be made.

Examples of sudden changes include: a company is presented with a buy-out offer by another firm; a disaster occurs, such as an oil spill, which may impact a firm's stock price; monetary or fiscal policy changes are implemented by the government. It is important for an investment system to be flexible and fast enough to evaluate the impact these changes may have on a security portfolio.

The current system allows for estimates of partial monthly returns to be calculated on any day of the month, for these returns to be used in the optimization process, and for the results of the analysis to be completed within a few minutes.

One advantage of the current system is that analysis of the current investment opportunities can be completed rapidly and recommendations for buying and selling securities can be quickly generated. This allows investment decisions to be made and implemented quickly with confidence.

Further illustrations of the invention are exemplified by various historical simulations shown in FIGS. 2-4 and Tables I-III which are taken over the time period of 1975 to 1987. As listed in Table I and in FIGS. 2 and 3, the liability stream for a selected pension plan can undergo substantial variation with time. A portfolio of assets has been analyzed in accordance with the preferred statistical method described hereinbefore, and details of the selected portfolio are set forth in Tables IV-X. Over the 1975-1987 time period, the resulting portfolio of assets shows substantially better correlation to the liability stream as compared to the Standard & Poors 500 return. Moreover, as seen in Table II and FIG. 4, the overall cumulative return for the portfolio of assets selected by the preferred method is far better than the Standard & Poors 500. The greatly enhanced stability and good

TABLE I

Funding Return Analysis

Year	Total Spanning Return (A)	Total S&P 500 Return (B)	Liability Return (C)	Spanning Funded Status Return (1+A)/(1+C)	S&P 500 Funded Status Return (1+B)/(1+C)
1975	28.85%	37.36%	7.43%	19.94%	27.86%
1976	34.96	23.94	15.53	16.83	7.28
1977	-4.16	-7.29	1.16	-5.25	-8.35
1978	4.76	6.42	-0.27	5.05	6.71
1979	21.84	18.36	-0.56	22.52	19.03
1980	13.68	32.34	-2.64	16.76	35.92
1981	16.01	-4.95	2.23	13.49	-7.02
1982	32.60	21.49	39.64	-5.04	-13.00
1983	22.15	22.43	0.46	21.59	21.87
1984	6.86	6.18	14.97	-7.05	-7.65
1985	40.95	31.59	31.33	7.33	0.20
1986	30.04	18.64	26.07	3.15	-5.89
1987	0.87	5.28	-5.05	6.24	10.88

TABLE II

Spanning Technology

Historic Simulation

Cumulative Surplus Analysis

Year	Spanning Portfolio		S&P 500 Index	
	Cumulative Dollar Value	Cumulative Funded Position	Cumulative Dollar Value	Cumulative Funded Position
	$100.00	100.00%	$100.00	100.00%
1975	118.78	119.65	127.12	128.05
1976	149.36	140.49	147.26	138.52
1977	133.59	133.82	126.88	127.10
1978	130.14	141.83	125.03	136.25
1979	148.14	177.42	137.62	164.83
1980	157.98	216.50	170.79	234.06
1981	173.32	263.84	152.84	232.66
1982	218.19	267.96	173.99	213.68
1983	256.52	348.87	202.88	275.93
1984	263.48	350.40	205.10	272.76
1985	359.74	403.26	258.85	290.17
1986	457.65	438.20	297.13	284.50
1987	453.01	496.15	304.26	333.22

Note: The above cumulative values reflect monthly payments to beneficiaries.

TABLE III

Spanning Technology

Historic Simulation

Year	Spanning Portfolio Return	Beta	Alpha
1975	28.85%	0.778	0.04%
1976	34.96	0.818	11.67
1977	-4.16	0.940	2.59
1978	4.76	0.859	-1.76
1979	21.84	0.956	3.31
1980	13.68	0.569	-8.15
1981	16.01	0.876	17.80
1982	32.60	0.829	10.39
1983	22.15	1.168	-2.03
1984	6.86	0.832	0.11
1985	40.95	1.052	6.09
1986	30.04	0.952	10.09
1987	0.87	0.887	-4.64

Electric, Gas, and Sanitation Utilities and Banking Restricted to 10% of Portfolio.

*1975 to 1987 Results:	Spanning Portfolio	S&P 5 Inde
Alpha - risk adjusted	4.33%	0.0(
Beta - risk adjusted	0.77	1.00
Average Return	19.2%	16.3%
Correlation to Liability	69.6%	33.3%
Return Volatility	13.6%	13.6%
Funding Return Volatility	10.1%	15.0%
Beginning Portfolio (1/75)		
Dividend Yield	5.53%	3.41%
P/E	7.2	7.7
Ending Portfolio (1/87)		
Dividend Yield	5.23%	4.0(
P/E	16.8	16.0

Duration of Liabilities at a 9% Interest Rate 9.61 yrs

*Note: results are based on annual returns

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TABLE IV

SPANNING PORTFOLIO COMPOSITION
1987 Portfolio

Industry	% of Portfolio
Food Kindred Products	12.10
Textile Mill Products	2.57
App. & Oth. Fin. Prod.	.80
Furniture and Fixtures	2.39
Printing Publishing and A.P.	2.73
Chemical and Allied Prod.	8.85
Primary Metal Industries	.81
Fab. Metal Industries	1.34
Machinery Except Electrical	8.42
Ele. and Ele. Mach.	2.50
Meas. Anal. & Cont. Inst. Etc.	6.76
Transportation By Air	5.16
Communication	2.89
Electirc Gas And Sanit. Serv.	10.00
Wholesale Trade-Durable Goods	.46
Wholesale Trade-Nondur. Goods	1.56
General Merch. Stores	1.88
Food Stores	3.00
Eating And Drinking Places	2.40
Banking	7.17
Cred. Agen. Oth. Than Banks	3.00
Insurance Carriers	2.36
Hold. and Other Inv. Comp.	2.90
Hotels Room. Houses Camp AOLP	.17
Health Services	1.76
Miscellaneous Services	3.00
Nonclassifiable Establishments	3.00

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TABLE V

SIMULATION RESULTS
1975
HISTORIC SIMULATION:

LIABILITY STREAM USED LONG TERM STUDY ABO

NUMBER	WEIGHT	SIC #	IDC	SECURITY NAME
1	3.00	67	BTC	BELL CANADA ENTERPRISES
2	3.00	63	CBB	CHUBB CORP
3	3.00	33	X	USX CORP
4	3.00	35	HR	NAVISTAR INTL CORP
5	3.00	54	WIN	WINN DIXIE STORES INC
6	3.00	13	CBI	CBI INDS INC
7	3.00	49	WWP	WASHINGTON WTR PWR CO
8	3.00	29	AHC9	AMERADA HESS CORP
9	3.00	35	UT	UNITED TELECOMMUNICATIONS
10	3.00	10	AMX	AMAX INC
11	3.00	67	ASA	ASA LTD
12	3.00	49	PGN	PORTLAND GEN CORP
13	3.00	64	AXD	ALEXANDER & ALEXANDER SVCS
14	3.00	13	KMG	KERR MCGEE CORP
15	3.00	48	T	AMERICAN TEL & TELEG CO
16	3.00	63	CIC	CONTINENTAL CORP
17	3.00	60	FBG1	BANC ONE CORP
18	3.00	33	NS	NATIONAL INTERGROUP INC
19	3.00	26	KMB	KIMBERLY CLARK CORP
20	3.00	36	MSU9	MATSUSHITA ELEC INDL
21	3.00	13	GAS	NICOR INC
22	3.00	49	CPL	CAROLINA PWR & LT CO
23	3.00	37	UA	UNITED TECHNOLOGIES CORP
24	3.00	64	MMC	MARSH & MCLENNAN COS INC
25	3.00	12	BNI	BURLINGTON NORTHN INC
26	3.00	20	K	KELLOGG CO
27	3.00	63	UFY	USF&G CORP
28	3.00	34	AC	PRIMERICA CORP
29	3.00	13	SN	AMOCO CORP
30	3.00	27	DNY	DONNELLEY RR & SONS CO
31	2.23	10	AL	ALCAN ALUM LTD
32	1.92	33	IAD	INLAND STL INDS INC
33	1.63	32	PPG	PPG INDS INC
34	1.41	60	FML	FIRST BK SYS INC
35	1.00	49	PLT	PACIFIC LTG CORP
36	0.83	67	LEM	LEHMAN CORP
37	0.51	10	UNP	UNION PAC CORP
38	0.48	13	OXY	OCCIDENTAL PETE CGPCR

TABLE VI

SIMULATION RESULTS
1980
HISTORIC SIMULATION:

LIABILITY STREAM USED LONG TERM ABO

NUMBER	WEIGHT	SIC #	IDC	SECURITY NAME
1	3.00	49	NMK	NIAGARA MOHAWK PWR CORP
2	3.00	28	IFF	INTERNATIONAL FLAVORS & FR
3	3.00	60	MNK	MELLON BANK CORPORATION
4	3.00	36	WHR	WHIRLPOOL CORP
5	3.00	60	NOB	NORWEST CORP
6	3.00	26	KMB	KIMBERLY CLARK CORP
7	3.00	28	WLA	WARNER LAMBERT CO
8	3.00	20	RAL	RALSTON PURINA CO
9	3.00	49	KGE	KANSAS GAS & ELEC CO
10	3.00	28	BOR	BORG WARNER CORP
11	3.00	26	UCC	UNION CAMP CORP
12	3.00	60	CHL	CHEMICAL NEWYORK CORP
13	3.00	20	K	KELLOGG CO
14	3.00	30	GT	GOODYEAR TIRE & RUBR CO
15	3.00	49	POM	POTOMAC ELEC PWR CO
16	3.00	13	LLX	LOUISIANA LD & EXPL CO
17	3.00	28	PG	PROCTER & GAMBLE CO
18	3.00	53	FDS	FEDERATED DEPT STORES INC
19	3.00	33	NS	NATIONAL INTERGROUP INC
20	3.00	26	FHP	FORT HOWARD CORP
21	3.00	20	BN	BORDEN INC
22	3.00	20	GIS	GENERAL MLS INC
23	3.00	34	AC	PRIMERICA CORP
24	3.00	28	GLXO	GLAXO HLDGS PLC
25	3.00	34	GS	GILLETTE CO
26	3.00	37	GM	GENERAL MTRS CORP
27	3.00	23	ISS	INTERCO INC
28	3.00	48	T	AMERICAN TEL & TELEG CO
29	3.00	20	CPB	CAMPBELL SOUP CO
30	3.00	36	GNB	GOULD INC
31	2.33	37	ML	MARTIN MARIETTA CORP
32	2.06	37	F	FORD MTR CO DEL
33	2.05	36	C	CHRYSLER HLDG CO
34	1.00	49	PPL	PENNSYLVANIA PWR & LT CO
35	1.00	60	AXP	AMERICAN EXPRESS CO
36	0.95	32	OCF	OWENS CORNING FIBERGLAS CO
37	0.62	20	PSY	PILLSBURY CO

TABLE VII

1975 INDUSTRY WEIGHTINGS

Electric, Gas and Sanitation Utilities, and Banking Restricted to 10% of Portfolio.

Code	Industry	% of Portfolio
10	Metal Mining	5.74%
12	Bituminous Coal & Lignite Min.	3.00
13	Oil & Gas Extraction	12.48
20	Food Kindred Products	3.00
26	Paper and Allied Products	3.00
27	Printing Publishing and A.P.	3.00
29	Petroleum Refin. & Rel. Prod.	3.00
32	Stone Clay Glass & Conc. Prod.	1.63
33	Primary Metal Industries	7.92
34	Fab. Metal Prod. Ex. M.&T.E.	3.00
35	Machinery Except Electrical	6.00
36	Ele. and Ele. Mach.	3.00
37	Transportations Equipment	3.00
48	Communication	3.00
49	Electric Gas and Sanit. Serv.	10.00
54	Food Stores	3.00
60	Banking	4.41
63	Insurance Carriers	9.00
64	Ins. Agents Brok. Serv.	6.00
67	Hold. and Other Inv. Comp.	6.83

SPANNING PORTFOLIO
1/1/75

	(000,000)
Market Capitalization	
Average	$1,203
High	$8,393
Low	$ 137
	(000)
Shares Outstanding	
Average	74,840 shares
Dividend Yield	5.1%
Price Earning Ratio	13.1x
Number of Stocks	38
Turnover 1975-1976	21.3%

TABLE VIII

1980 INDUSTRY WEIGHTINGS

Electric, Gas and Sanitation Utilities, and Banking Restricted to 10% of Portfolio.

Code	Industry	% of Portfolio
13	Oil	3.00%
20	Food Kindred Products	15.62
23	App. & Oth. Fin. Prod.	3.00
26	Paper and Allied Products	9.00
28	Chemical and Allied Prod.	15.00
30	Rubber and Misc. Plast. Prod.	3.00
32	Stone Clay Glass & Conc. Prod.	0.95
33	Primary Metal Industries	3.00
34	Fab. Metal Prod. Ex. M.&T.E.	6.00
36	Ele. and Ele. Mach.	8.05
37	Transportations Equipment	7.38
48	Communication	3.00
49	Electric Gas and Sanit. Serv.	10.00
53	General Merch. Stores	3.00
60	Banking	10.00

SPANNING PORTFOLIO
1/1/80

Market Capitalization	(000,000)
Average	$1,790
High	$13,311
Low	$ 247
Shares Outstanding	(000)
Average	130,229 shares
Dividend Yield	6.9%
Price Earning Ratio	6.6x
Number of Stocks	37
Turnover 1980-1981	30.4%

TABLE IX

SIMULATION RESULTS -
1985
HISTORIC SIMULATION:

LIABILITY STREAM USED LONG TERM STUDY ABO

NUMBER	WEIGHT	SIC #	IDC	SECURITY NAME
1	3.00	53	JCP	PENNEY J C INC
2	3.00	49	HE	HAWAIIAN ELEC I
3	3.00	58	MCD	MCDONALDS CORP
4	3.00	60	SEK	SOUTHEAST BKG C
5	3.00	23	RML	RUSSELL CORP
6	3.00	28	AVP	AVON PRODS INC
7	3.00	60	MFT	MANUFACTURERS HAN
8	3.00	99	TBILL	CASH: TBILLS 0.0
9	3.00	49	DPL	DPL INC
10	3.00	35	MFL	MILLIPORE CORP
11	3.00	20	UL	UNILVER PLC
12	3.00	38	EK	EASTMAN KODAK C
13	3.00	27	CKH	COMMERCE CLEARI
14	3.00	28	SQB	SQUIBB CORP
15	3.00	28	PFE	PFIZER IND
16	3.00	20	KO	COCA COLA CO
17	3.00	45	DAL	DELTA AIR LINES
18	3.00	67	NES	NEW ENGLAND ELE
19	3.00	89	SW	STONE & WEBSTER
20	3.00	61	GWF	GREAT WESTN FIN
21	3.00	28	SKL	SMITHKLINE BECKMAN
22	3.00	28	SRG	SCHERING PLOUGH
23	3.00	51	SYY	SYSCO CORP
24	3.00	38	MMM	MINNESOTA MNG &
25	2.93	78	DIS	DISNEY WALT CO
26	2.68	25	HB	HILLENBRAND IND
27	2.66	49	BGE	BALTIMORE GAS & ELE
28	2.53	38	MDO	MEDTRONIC INC
29	2.30	73	KGS	KELLY SVCS INC
30	2.05	35	PRME	PRIME COMPUTER
31	1.77	28	SYN	SYNTEX CORP
32	1.76	16	FLR	FLUOR CORP
33	1.70	60	FBG1	BANC ONE CORP
34	1.54	63	AHN	AHMANSON H F &
35	1.35	49	AYP	ALLEGHENY PWR SYS
36	1.22	48	CTX	CENTEL CORP
37	1.09	20	CFG	CPC INTL INC
38	0.77	28	PG	PROCTER & GAMBLE
39	0.59	28	AHP	AMERICAN HOME PRODS
40	0.54	34	GS	GILLETTE CO
41	0.41	53	DNC	DAYTON HUDSON C
42	0.13	47	FEDX	FEDERAL EXPRESS

TABLE X

1985 INDUSTRY WEIGHTINGS

Electric, Gas and Sanitation Utilities, and Banking Restricted to 10% of Portfolio.

Code	Industry	% of Portfolio
		1.76%
16	Const. Oth Than B.C.-G.C.	7.09
20	Food Kindred Products	3.00
23	App. & Oth. Fin. Prod.	2.68
25	Furniture and Fixtures	3.00
27	Printing Publishing and A.P.	18.13
28	Chemical and Allied Prod.	0.54
34	Fab. Metal Prod. Ex. M.&T.E.	5.05
35	Machinery Except Electrical	8.53
38	Meas. Anal. & Cont. Inst. Etc.	3.00
45	Transportation By Air	0.13
47	Transportation Services	1.22
48	Communication	10.00
49	Electric Gas and Sanit. Serv.	3.00
51	Wholesale Trade-Nondur. Goods	3.41
53	General Merch. Stores	3.00
58	Eating and Drinking Places	7.70
60	Banking	3.00
61	Cred. Agen. Oth. Than Banks	1.54
63	Insurance Carriers	3.00
67	Hold. And Other Inv. Comp.	2.30
73	Business Services	2.93
78	Motion Pictures	3.00
89	Miscellaneous Services	3.00
99	Nonclassifiable Establishments	

SPANNING PORTFOLIO
1/1/85

	(000,000)
Market Capitalization	
Average	$3,045
High	$11,689
Low	$ 373
	(000)
Shares Outstanding	
Average	97,120 shares
Dividend Yield	4.0%
Price Earning Ratio	11.0x
Number of Stocks	41
Turnover 1985-1986	15.0%

Table XI
ANALYSIS OF PROGRAM SIMULATION

Target & Index represent the Standard & Poors 500 Stock Index portfolio represent optimizer chosen portfolio.
One example of the benefits of the technique are seen in the monthly statistics, where the annualized standard deviation of returns is 14.6% for the optimized portfolio vs. 16.04 for the S&P 500.

ANNUALIZED MONTHLY STATISTICS

	MEAN	STD DEV	SKEW * 10^6
Target	15.88%	16.04%	-50.00
Portfolio	17.97%	14.60%	-19.72
Portfolio Diff	2.09%	4.40%	.01
Index	15.88%	16.04%	-50.00
Index Diff	.00%	.00%	.00

ANNUALIZED QUARTERLY STATISTICS

	MEAN	STD DEV	SKEW * 10^6
Target	16.18%	17.04%	-172.12
Portfolio	18.40%	16.19%	-41.29
Portfolio Diff	2.23%	3.99%	1.58
Index	16.18%	17.04%	-172.12
Index Diff	.00%	.00%	.00

ANNUAL STATISTICS

	MEAN	STD DEV	SKEW * 10^6
Target	16.38%	13.63%	-670.98
Portfolio	19.01%	13.43%	-61.67
Portfolio Diff	2.63%	4.43%	-23.31
Index	16.38%	13.63%	-670.98
Index Diff	.00%	.00%	.00

statistical correlation with the liability return is further evident in Table III and FIG. 5, wherein detailed comparisons are made between the selected portfolio of assets and the standard liability return.

In FIG. 6 a range of simulation funding returns for the portfolio of assets are compared with a typical pension fund a mixture of stocks, bonds, real estate and treasury bills. Clearly, the risk is much higher for the typical pension fund; and dramatic improvement in the return, or reduction of risk, results when only 35% of the standard pension fund is modified using the method of the invention.

In another embodiment, a portfolio of assets can be constructed by selecting a portion of a total portfolio with assets having optimal correlation of asset return to a liability or financial index. The remainder of the portfolio comprises futures contracts which are combined with the correlated portfolio portion to achieve in effect an optimum correlation for the entire portfolio of assets. Further details are set forth in Appendix IV.

In another aspect of one embodiment, control can be exerted over pension plan surplus by adjusting the level of risk selected for a portfolio of assets. As illustrated in FIG. 6, the expected return can be selected at various levels with the degree of risk, or standard deviation of the funding level, generally increasing as one moves from a position of

minimum risk at the top of the "bullet" to higher future returns. Control over a pension plan surplus, or for that matter any plan for which you wish to respond dynamically to control risk/return in concert, can be accomplished over a wide range of risk and return values. Such an approach can be used to manage return under variable risk positions and minimize insurance costs for protecting against underfunding of a plan, such as falling below a predetermined minimum floor. Consequently, as the funding level approaches 100% a minimum risk portfolio of assets should be constructed using the methods described hereinbefore. As the surplus accumulates, the acceptable risk level can be increased for the portfolio of assets by dynamic modification of the portfolio asset components. One can utilize futures contracts as an overlay for an underlying portfolio of assets, having been selected by the basic invention described previously, to create in effect an optimum statistical correlation for the entire portfolio, including the futures contracts. As the surplus approaches 10% - 20% excess, a portfolio of assets can be constructed resulting in a much higher level of future return. For example, in FIG. 6, the change in future return from minimum risk to the highest return data point is about a 35% greater return but with an accompanying 70% - 80% increase in standard deviation compared to the minimum risk point.

In a further embodiment of the invention one can overcome problems associated with an indefinite covariant matrix. The current system and method does not use the full covariance matrix to extract a partial derivative to guide the search process, and thus it is not subject to one of the failures that results using standard quadratic programming.

To us standard quadratic programming algorithums the covariance matrix must be positive semi-definite, or positive definite. This means technically that no row of the matrix can be replicated by a linear combination of other rows.

However, this condition occurs when there are fewer returns than the number of securities under consideration. This is a significant shortcoming of the standard methodlogy. For example, to consider five hundred securities simultaneously, the user must supply at least five hundred and one returns for each security being considered. If monthly data is being used for the return series, at least forty-one years of data must be available for each security under consideration. Most securities have not been in existence for this period of time.

If not enough returns are available or if the matrix is indefinite, the standard quadratic solution techniques will fail to find a solution point that is optimal.

The current system allows a solution, which is at least as good as any other feasible solution, to be achieved without regard to the sensitivity of the covariance matrix.

Problems that otherwise could not be solved by standard technologies are solved by the current system. This allows practical portfolios to be selected even though there is limited available return information.

In another aspect of the invention involving practical applications of the current methodology to managing security portfolios, the ability to invest dividend income and other cash flows efficiently is also an important element in effective management. The current system allows a portfolio manager to invest available cash in the most efficient securities while considering the current portfolio holdings. Effectively this allows the manager to invest in securities which best enhance the current portfolio position without selling any of the current holdings. In a practical portfolio management system the ability to reinvest cash flows efficiently is always an important consideration. The current system provides this ability. An illustration of a reinvestment solution is provided in Appendix V which lists data used and results obtained in performing the reinvestment method.

In addition to finding optimal portfolios for tracking financial targets, the current system allows other objectives to be considered and incorporated in the solution. Examples include supplementing the basic objective function with an income objective, tax impact objective, or a company cash flow

objective. The system is flexible enough to allow the objective function to be customized for particular applications.

As an example, an investor who has a preference for securities with high dividend yields will specify an objective function which explicitly states the trade off between portfolio tracking and dividend income. The computer routine to optimize a portfolio (the optimizer) will extract the partial derivatives of this objective function and proceed to select an optimal portfolio which exactly incorporates the specified trade-off between dividend income and tracking. This investor then has a custom solution which addresses his particular concerns and requirements.

The consideration of transaction costs associated with buying and selling securities is incorporated into the portfolio optimization system to control expenses due to trading. The trade off between tracking accuracy and transaction costs can be specified by the investor. This allows for a customized objective function, with regard to expected transaction costs, for each client.

Investors may also have tax effects to consider when trading from one security to another. The taxable gains and losses and their impact on expected return can be specified by the investor so as to control these costs.

Another preference which can be incorporated into the objective function and handled explicitly by the optimization

system is the consideration of cash flows. An investor may have a preference for investing in companies which have large and positive cash flows. This objective can be incorporated into the system and resulting portfolios will reflect this investment goal.

While preferred embodiments of the present invention have been illustrated and described, it will be understood that changes and modifications can be made therein without departing from the invention to its broader aspects. Various features of the invention are defined in the following claims.

APPENDICES TO SPECIFICATION

APPENDIX I - Spanning Program for creating an optimal target tracking portfolio of securities (Appendix I pp. 1-27). Also includes 4 pages of Output.

APPENDIX II - Liability Return Program for creating a return series for a liability stream from yields (Appendix II pp. 1-2).

APPENDIX III - Correlation Portfolio Program for creating an optimal index correlation portfolio with securities (Appendix III pp. 1-30).

APPENDIX IV - "Fasttrack" Program for analyzing large numbers of securities in a rapid, efficient manner to provide optimum correlation of asset return to a time dependent financial index. Substantial computer memory storage reduction is also achieved.

APPENDIX V - Data listing of method for reinvestment of available cash flow beginning from a current portfolio.

APPENDIX VI - Example illustrating distinctions between current system and prior art.

APPENDIX I

SPANNING PROGRAM

To create an optimal target tracking portfolio of securities.

(Appendix I pp. 1- 27)

```
        TURN = XNUM*(100./(TURN1+.01)-100.0/100.01)
      END IF
C     ********************   CALL COVIN TO READ IN RETURNS     ******
      CALL COVIN (NUM,IREAD,IFIRST,ILAST)

C     ********************   CALL HOLDING TO FOR CURRENT WEIGHTS ****
      CALL HOLDING (NUM,HOLD,IPORT)

C     ********************   CALL MATRIX TO CALCULATE  INPUT ARRAYS *
      WRITE(*,101)'CALLING MATRIX  ........      '
      CALL MATRIX (NUM,IREAD)

C     ***************************************************************
      WRITE(*,101)'CALLING BOUNDS  .......      '
      CALL BOUNDS (NUM,ICOL,MMM)

C     ***************************************************************

C     ********************   CALL TO OPTIMIZER     ******************

      WRITE(*,101)'CALLING OPTIMIZER  ......    '
      IF (ICOUNT.EQV. .TRUE.) THEN
         WRITE(*,102)'WORKING ON RUN NUMBER    ',ISKIP
      END IF

      MAXWS = 3*(2*NUM+ID)*(2*NUM+ID)+8*(2*NUM+ID)+6
      ITURN = 0
      CALL QSET ( NUM, MAXWS,ITURN )
C     *********    IF TURNOVER IS CONSIDERED, CALL TURNOV

      IF(TURN .GT. 0.0) THEN
         ITURN = 1
         CALL QSET (NUM, MAXWS, ITURN)
      END IF


C     ********************   CALL TO PORTFOLIO OUTPUT     ***************
      WRITE(*,*)
      WRITE(*,101)'CALLING PORT  ..........     '
      CALL PORT (NUM)
      IF (IDUMMY .EQ. 1) GO TO 100

C     ********************    CALL TO STATISTICAL TRACKING      *********
      WRITE(*,101)'CALLING TRACKER  .......     '
      CALL TRACKER (NUM,IREAD)

C     ********************    CALL TO TURNOVER ROUTINE          *********
      WRITE(*,101)'CALLING BAL  ...........     '
      CALL BAL (NUM)
C     ***************************************************************

100   WRITE(*,101)'SPANNING SIMULATION COMPLETE'
```

```
         IF (HOLDEX .EQV. .FALSE.) THEN
            WRITE(*,*)'FILE NOT FOUND ',HOLD
            GO TO 11
         END IF
      END IF
C     ********************  ICOUNT  IS TRUE  --> CALL MULTRUN   ********
      ELSE
           WRITE(*,101)'CALLING MULTRUN  .......     '
           CALL MULTRUN(ISKIP)
      END IF

C     ********************       CALL SAVDAT TO SAVE   PAST.DAT      ***
      CALL SAVDAT
C     ***************************************************************

      NM = NMSAVE
      NM = (INT(NM/100)-80)*12+(NM-INT(NM/100)*100)
      IREAD = NSTAT+NSIMS

      IF(NSTOCKS.GT.0)THEN
        XBUPPER = SMAX
      END IF

C**********  SET UP CONSTANTS ********************

      NUM = NSTOCKS+NBONDS
      IF(NUM.GT.ND)THEN
          WRITE(*,*)' WARNING NUM >',ND,' TOO BIG FOR PROGRAM'
          STOP
      ENDIF

      ICOL = ID
      KE = KEQ
      KKK = KE
      IA = ND
      ICC = ND
      IH = N2D

      IFIRST = NM-NSTAT
      ILAST = NM+NSIMS-1

      BULL1 = BULLET
      TARG1 = TARGET
      TURN1 = TURN

      BULLET = BULLET*ABS(BULLET)/1000.
      IF (TURN1.EQ.100.)THEN
         TURN = 0.0
      ELSE
C        WRITE(*,*)'INPUT NUMERATOR'
C        READ(*,*)XNUM
         XNUM = 0.10
```

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```
C UPDATE  December 6, 1988
C ****************************************************************
      PROGRAM SPAN
C ****************************************************************

      INCLUDE 'COMMON.F'
      CHARACTER*30 HOLD
      LOGICAL ICOUNT
      LOGICAL HOLDEX

C *************   WRITE COPYRIGHT TO SCREEN    ****************

      INCLUDE 'COPYRIGHT.F'

C ****************************************************************


C *************          DATA INPUT SECTION     ************************

5     CONTINUE

C     DEFAULT READ IN OF 24 MONTHS PRIOR  = NSTAT, NRESTS FOR B( ) ****

      NSTAT = 24
      NRETS = 24
      BULLET = 0.0
      TARGET = 1.
      TURN = 100.
      ITYPE = 1
      ICHANGE = 0
      XBLOWER = .0D0
      XBUPPER = 3.0D0
      SMAX = XBUPPER

C   *********************          CALL FLASH TO INTRODUCE   S P A N   ****
C     CALL FLASH

C   *************  IF 'COUNTS' EXISTS THIS IS A MULTIPLE RUN       ****
      INQUIRE (FILE = 'COUNTS', EXIST = ICOUNT)

      IF (ICOUNT .EQV. .FALSE.)   THEN
C   *********************          CALL INTRO TO INPUT PARAMETERS      ****
         CALL INTRO
C   *********************          CALL MODIFY TO CHANGE PARAMETERS    ****
         CALL MODIFY
C   *********************          READ IN THE HOLDINGS FILE           ****
      IF(IHOLD .NE. 0) THEN
11    WRITE(*,*)'INPUT PORTFOLIO #, AND NAME OF HOLDINGS FILE'
      READ(*,*)IPORT,HOLD
      INQUIRE (FILE = HOLD,EXIST = HOLDEX)
```

```
      CLOSE(13)
      RETURN

C *****    STOP  DONE WITH MULTI RUN     **********
99    CLOSE(13)
      WRITE(*,*)'DONE WITH MULTIPLE RUN ********************'
      STOP
      END
*******************     END OF SUBROUTINE  MULTRUN     ******************
*******************************************************************************
      SUBROUTINE HOLDING (NUM,HOLD,IPORT)
*******************************************************************************
      INCLUDE 'COMMON.F'

      DIMENSION VAL(ND)
      CHARACTER*9 SYMBL,IDCSYM(ND)
      CHARACTER*30 HOLD


C **** IHOLD IS READ FROM FIRST SCREEN RESPONSE: OLD OR HOLDINGS RUN **
      IF (IHOLD .EQ. 0) GO TO 999

      )PEN (25,FILE = HOLD,STATUS = 'OLD')

11    (PORT = REAL(IPORT)
        = 0
22    READ(25,*, END = 44)SYMBL,VALUE
      F (SYMBL .EQ. 'IDCSYMBL') THEN
         IF (VALUE .EQ. XPORT) THEN
            READ(25,*,END = 44)GARB
33          READ(25,*, END = 44)SYMBL,VALUE
              IF (SYMBL .EQ. 'IDCSYMBL') GO TO 44
                 I = I + 1
                 IDCSYM(I) = SYMBL
                 VAL(I) = VALUE
                 GO TO 33
         END IF
      READ(25,*,END = 44) GARB
      END IF
      GO TO 22

44    CONTINUE
      NIDC = I
      IF (NIDC .EQ. 0)THEN
         WRITE(*,*)'PORTFOLIO NUMBER NOT FOUND ', IPORT
         WRITE(*,*)'ENTER PORTFOLIO NUMBER AGAIN'
         READ(*,*)IPORT
         REWIND(25)
         GO TO 11
      END IF

      IF (ICOUNT.EQV. .TRUE.) THEN
         WRITE(*,102)'DONE WITH RUN NUMBER     ',ISKIP
         GO TO 5
      END IF

101   FORMAT('+',A50)
102   FORMAT('+',A50,I7)


      END
C                  END OF MAIN PROGRAM SPAN1
C   ***************************************************************************
*******************************************************************************
      SUBROUTINE MULTRUN (ISKIP)
*******************************************************************************

      INCLUDE 'COMMON.F'
      CHARACTER*30 XTITL,XFLOUT,XLIBIN,XSTKIN,XBNDIN

      OPEN (13,FILE ='MULTIN',STATUS = 'OLD')

      IF (ISKIP.EQ.0) GO TO 30

      DO 10 I = 1, ISKIP
         DO 20 J = 1,18
         READ(13,'(A1)',END = 99)GARB
20       CONTINUE
10    CONTINUE

30    CONTINUE
      READ(13,101,END = 99)TITLE
      READ(13,101, END = 99) FILEOUT
      READ(13,101, END = 99) LIABIN
      READ(13,101, END = 99) STOCKIN
      READ(13,101, END = 99) BONDIN
      READ(13,*, END = 99) NMSAVE
      READ(13,*, END = 99) NSIMS
      READ(13,*, END = 99) NSTOCKS
      READ(13,*, END = 99) NBONDS
      READ(13,*, END = 99) IDUMMY
      READ(13,*, END = 99) STOCKMIN
      READ(13,*, END = 99) YIMAX
      READ(13,*, END = 99) SMAX
      READ(13,*, END = 99) NSTAT
      READ(13,*, END = 99) NRETS
      READ(13,*, END = 99) BULLET
      READ(13,*, END = 99) TARGET
      READ(13,*, END = 99) TURN

101   FORMAT (A20)

      ISKIP = ISKIP+1
```

```
      ICASH = 0
      PORTVAL = 0.0
      DO 10 I=1,NIDC
         PORTVAL = PORTVAL + VAL(I)
         IF (IDCSYM(I) .EQ. 'CASH')THEN
            ICASH = I
            TEMP = VAL(I)
            VAL(I) = VAL(1)
            VAL(1) = TEMP
            GARB = IDCSYM(I)
            IDCSYM(I) = IDCSYM(1)
            IDCSYM(1) = GARB
         END IF
10    CONTINUE
      IF (ICASH .EQ. 0) THEN
         WRITE(*,*)'NO CASH INCLUDED....PROGRAM STOPPING'
         STOP
      END IF

      IDCTEST = 0
      NCOUNT = 0
      DO 20 I = 2,NIDC
         ITEST = 0
         DO 30 J = 1,NUM
           IF(IDC(J)(1:4) .EQ. IDCSYM(I)) THEN
              ITEST = 1
              NCOUNT = NCOUNT+1
              OLDWT(J) = VAL(I) / PORTVAL
           END IF
30       CONTINUE
      IF (ITEST .EQ. 0) THEN
         IDCTEST = 1
         WRITE(*,*)IDCSYM(I),': SYMBOL NOT INCLUDED IN RETURN FILE'
      END IF
20    CONTINUE

      IF (IDCTEST.EQ.1) THEN
        WRITE(*,*)NIDC-NCOUNT-1,'SYMBOLS NOT FOUND..PROGRAM STOPPING'
        STOP
      END IF
      RETURN


999   OPEN(21,FILE = 'OLD',STATUS = 'OLD')
      DO 90 I = 1,NUM
         READ(21,*)OLDWT(I)
         IF (TURN.EQ. 0.0)OLDWT(I)=0.0
         OLDWT(I) = OLDWT(I)/100.
90    CONTINUE
      CLOSE(21)
      RETURN
      END
C ********************     END OF SUBROUTINE  HOLDING     **************
C  UPDATE December 6, 1988
C  ************  THIS SUBROUTINE READS IN STOCK, BOND & LIA DATA *******

      SUBROUTINE COVIN (NUM,IREAD,IFIRST,ILAST)

C  ***************************************************************************

C              IFIRST IS FIRST MONTH OF DATA NEEDED FOR MATRIX
C              ILAST IS LAST MONTH OF SIMULATION
C
      INCLUDE 'COMMON.F'

C ******************   READ IN LIABILITY RETURNS **********************

      OPEN (9,FILE = LIABIN, STATUS = 'OLD')

      READ (9,111) LIANAME
      WRITE(*,*)LIANAME
      DO 200 I = 1,5
         READ (9,111) GARB
200   CONTINUE

      READ (9,*) ISTART
      READ (9,*) ISTOP

      DO 300 I = 1,IFIRST-ISTART
         READ (9,111) GARB
300   CONTINUE

      DO 400 I = 1,IREAD
         READ (9,*) ANIM(I)
400   CONTINUE

      CLOSE(9)

C                                          READ IN STOCK DATA
      IF (NSTOCKS.GT.0) THEN
         OPEN (4,FILE = STOCKIN, STATUS = 'OLD')

         DO 600 I = 1,IDUMMY
            READ (4,111) (GARB,L = 1,6)
            READ (4,*) ISTART
            READ (4,*) ISTOP
           DO 610 K = 1,ISTOP-ISTART+1
            READ (4,*) XGARB
610        CONTINUE
600      CONTINUE
111   FORMAT (A40)

         DO 700 I = 1,NSTOCKS
```

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```
783          READ (4,111,END = 785) NAME(I)

C  **** CUT OFF LEADING BLANKS OF NAME(I)
          ILEN = 1
          GARB = '                    '
790       IF (NAME(I)(ILEN:ILEN) .EQ. ' ')THEN
             ILEN = ILEN+1
             GO TO 790
          ELSE
             GARB(1:LENGTH) = NAME(I)(ILEN:LENGTH)
          END IF
          NAME(I) = GARB

             WRITE (*,112) I,NAME(I)
112          FORMAT('+',' STOCK # ',I5,' IS ',A40)
             READ (4,111) GARB

C  **** CUT OUT BLANKS FROM GARB TO GET AN IDC AND TICKER
          READ (4,111) GARB
          ILEN = 1
          IDC(I) = '          '
791       IF (GARB(ILEN:ILEN).EQ.' ') THEN
             ILEN = ILEN + 1
             IF ((ILEN+3).GT.LENGTH) GOTO 793
             GOTO 791
          ENDIF

          IDC(I)(1:4) = GARB(ILEN:ILEN+3)
          ILEN = ILEN + 4

792       IF (GARB(ILEN:ILEN).EQ.' ') THEN
             ILEN = ILEN + 1
             IF ((ILEN+3).GT.LENGTH) GOTO 793
             GOTO 792
          ENDIF
          IDC(I)(6:9) = GARB(ILEN:ILEN+3)

793       CONTINUE

             READ (4,*) ISIC(I)
             IF(ISIC(I).GT.99) ISIC(I) = INT (ISIC(I)/100)
             READ (4,111) (GARB,L = 4,5)
             READ (4,*) ISTART
             READ (4,*) ISTOP

C *****      TEST FOR ENOUGH RETURNS TO SATISFY NRETS  ******************

             ICHECK = NM-NRETS-ISTART
             IF(ICHECK.LT.0) NRETS = NM - ISTART
             IF(NRETS.LT.NSTAT) ICHECK = IFIRST-ISTART

             DO 800 J = 1,ICHECK
                READ (4,111) GARB
800          CONTINUE

             DO 801 J = 1,NRETS-NSTAT
                READ(4,*)GARB
801          CONTINUE

             JJ = NRETS-NSTAT

             DO 810 K = 1,IREAD
              READ (4,*) RET(K,I)

C ****  ADJUST OCTOBER 1987 **********************
          IF(K+NM-NSTAT-1.EQ. 94)THEN
            IF(K.LE.NSTAT)RET(K,I)=RET(K,I)/2.97
          END IF
                J = JJ+K
810          CONTINUE

             DO 1200 J = 1,ISTOP-ILAST
                READ (4,111) GARB
1200         CONTINUE

700       CONTINUE
          ENDIF
1400      CONTINUE
          CLOSE(4)
C                                READ IN BOND DATA

          IF (NBONDS.GT.0) THEN
          OPEN (7,FILE = BONDIN, STATUS = 'OLD')

          DO 900 I = NSTOCKS+1,NSTOCKS+NBONDS
             READ (7,111) NAME(I)
             WRITE (*,113) I,NAME(I)
             READ (7,111) (GARB,L = 1,5)
             READ (7,*) ISTART
             READ (7,*) ISTOP
113          FORMAT('+','BOND  # ',I5,' IS ',A40)

C *****      TEST ICHECK FOR ENOUGH RETURNS FOR BRET   ******************

             ICHECK = NM-NRETS-ISTART
             IF(ICHECK.LT.0) THEN
             WRITE(*,*)'BOND ',I,' DOES NOT HAVE ENOUGH RETURNS FOR NRETS'
                STOP
             END IF
             IF(NRETS.LT.NSTAT) ICHECK = IFIRST-ISTART

             DO 1000 J = 1,ICHECK
                READ (7,111) GARB
1000         CONTINUE
```

```
          DO 1001 J = 1,NRETS-NSTAT
            READ(7,*)GARB
 1001     CONTINUE

          JJ = NRETS-NSTAT

           DO 1010 K =1,IREAD
          READ (7,*) RET(K,I)
            J = JJ + K
 1010      CONTINUE

          DO 1300 J = 1,ISTOP-ILAST
              READ (7,111) GARB
 1300     CONTINUE

  900   CONTINUE

        ENDIF
        CLOSE(7)
        RETURN

C ***     IF END OF FILE WAS HIT ON STOCKS - RESET NUM AND CONTINUE ***
  785   NSTOCKS = I-1
        NUM = NSTOCKS+NBONDS
         GOTO 1400

        END
C
C   ***************************************************** END OF SUBROUTINE COVIN

C ******************** MATRIX CALCULATION SUBROUTINE ********************
      SUBROUTINE MATRIX (NUM,IREAD)
C ***********************************************************************
      INCLUDE 'COMMON.F'

C                       IREAD = NSTAT+NSIMS
C                       NUM = NSTOCKS+NBONDS

      DO 233 I = 1,NUM
         DO 244 J = 1,NSTAT
            RET(J,I) = RET(J,I)-ANIM(J)*TARGET
 244     CONTINUE
 233  CONTINUE

      DO 213 I = 1,NUM
          AVE(I) = 0.0
          B(I) = 0.0
          DO 214 J = 1,NRETS
             AVE(I) = AVE(I)+RET(J,I)/DBLE(NRETS)
 214  CONTINUE
```

```
          B(I) =  AVE(I)*BULLET
 213  CONTINUE

C ********        CALCULATE COVARIANCE MATRIX  **********
      DO 215 I = 1,NUM
         DO 215 J = I,NUM
            A(I,J) = 0
            DO 215 K = 1,NSTAT

         XXX = DBLE (NSTAT-1)

      A(I,J) = A(I,J)+(RET(K,I)-AVE(I))*(RET(K,J)-AVE(J)) / XXX
      A(J,I) = A(I,J)

      IF(A(I,J).GT.50)WRITE(*,*)'COV TOO BIG',A(I,J),I,J
 215  CONTINUE

      RETURN

      END
C
C   ***************************************************** END OF SUBROUTINE MATRIX

C   ************************** SUBROUTINE BOUNDS ********************
      SUBROUTINE BOUNDS (NUM,ICOL,MMM)
C   *****************************************************************

      INCLUDE 'COMMON.F'

      SCAL = 1.25
      SIC49 = 0.0
      SIC60 = 0.0
      SIC63 = 0.0
      SIC67 = 0.0


      DO 80 I = 1,NUM
         BDL(I) = XBLOWER/100.0
         BDU(I) = XBUPPER/100.0
         IF(OLDWT(I).GT.BDU(I))THEN
           IF(OLDWT(I).GT.SCAL*BDU(I)) THEN
             BDU(I) = SCAL*BDU(I)
           ELSE
             BDU(I) = OLDWT(I)
           END IF
         END IF
         IF (I.GT.NSTOCKS) BDU(I) = 1.

         IF(ISIC(I).EQ.48) SIC49 = SIC49+OLDWT(I)
         IF(ISIC(I).EQ.49) SIC49 = SIC49+OLDWT(I)
         IF(ISIC(I).EQ.60) SIC60 = SIC60+OLDWT(I)
         IF(ISIC(I).EQ.63) SIC63 = SIC63+OLDWT(I)
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```
      IF(ISIC(I).EQ.67) SIC67 = SIC67+OLDWT(I)
80    CONTINUE

          D(1) =  STOCKMIN/100.0
          D(2) =  100.0/100.0
          D(3) = -100.01/100.0
          D(4) = -YIMAX/100.0
          D(5) = -YIMAX/100.0
          D(6) = -YIMAX/100.0

      SIC60S = SIC60+SIC63+SIC67
      IF(SIC49*100.GT.YIMAX.AND.SIC49*100.LT.SCAL*YIMAX)D(4) = -SIC49
      IF(SIC60S*100.GT.YIMAX.AND.SIC60S*100.LT.SCAL*YIMAX)D(5)=-SIC60S
      IF(SIC67*100.GT.YIMAX.AND.SIC67*100.LT.SCAL*YIMAX)D(6) = -SIC67

      IF( SIC49*100.GT.SCAL*YIMAX)  D(4) = D(4)*SCAL
      IF( SIC60S*100.GT.SCAL*YIMAX) D(5) = D(5)*SCAL
      IF( SIC67*100.GT.SCAL*YIMAX)  D(6) = D(6)*SCAL

          DO 51 J = 1,ICOL
             DO 52 I = 1,NUM
                C(I,J) = 0.0
                IF (J.EQ.1.AND.I.LE.NSTOCKS)  C(I,J) = 1.0
                IF (J.EQ.2) C(I,J) = 1.0
                IF (J.EQ.3) C(I,J) = -1.0
                IF (J.EQ.4.AND.ISIC(I).EQ.49)    C(I,J) =  -1.0
                IF (J.EQ.4.AND.ISIC(I).EQ.48)    C(I,J) =  -1.0
                IF (J.EQ.5.AND.ISIC(I).EQ.60)    C(I,J) =  -1.0
                IF (J.EQ.5.AND.ISIC(I).EQ.63)    C(I,J) =  -1.0
                IF (J.EQ.5.AND.ISIC(I).EQ.67)    C(I,J) =  -1.0
                IF (J.EQ.6.AND.ISIC(I).EQ.67)    C(I,J) =  -1.0

52           CONTINUE
51        CONTINUE

C     CLOSE (6)

      MMM = 2*NUM+ICOL

      RETURN

      END
C                              END OF SUBROUTINE BOUNDS
C ***************************************************************************

C   ***************************************************************************
      SUBROUTINE PORT (NUM)
C   ***************************************************************************

      INCLUDE 'COMMON.F'

C  ********    RESET THE RETURNS TO ORIGINAL STATE  ********************

      DO 1300 J=1,NUM
          DO 1300 I=1,NSTAT
              RET(I,J)=RET(I,J)+ANIM(I)*TARGET
              IF(I+NM-NSTAT-1.EQ.94)RET(I,J)=RET(I,J)*2.97
 1300 CONTINUE

C     ********************  BEGIN OUTPUT PROCEDURES **************
      UANIM = 0.0
      DO 129 I = 1,NRETS
      UANIM = UANIM + ANIM(I)/DBLE(NRETS)
129   CONTINUE
      UANIM = UANIM*TARGET
      IDUMMY = 0
      XTOT=0.
      DO 130 I=1,NUM
         XTOT=XTOT+X(I)
         CUM(I) = X(I)
          IF(X(I).LT. -0.001) THEN
      WRITE(*,*)' '
      WRITE(*,*)'**************   SPANNING RUN ABORTED   **************'
      WRITE(*,*)'  WEIGHT NUMBER ',I,' = %',X(I)*100.
      WRITE(*,*)'***********************************************************'
      IDUMMY = 1
      RETURN
      END IF

130   CONTINUE

      IF (ABS(XTOT-1.0) .GT. 0.005) THEN
      WRITE(*,*)' '
      WRITE(*,*)'**************   SPANNING RUN ABORTED   **************'
      WRITE(*,*)'  TOTAL WEIGHT IN PORTFOLIO = %',XTOT*100.
      WRITE(*,*)'***********************************************************'
      IDUMMY = 1
      RETURN
      END IF

C     *********************  PRINT SPANNING SIMULATION RESULTS ***

      OPEN(10,FILE=FILEOUT,STATUS='UNKNOWN')
      REWIND(10)

      WRITE(10,*)' NATIONAL INVESTMENT SERVICES SPANNING TECHNOLOGY'
      WRITE(10,*)'                SIMULATION RESULTS'
      WRITE(10,*)
      WRITE(10,*)'                ',TITLE
      WRITE(10,*)
      WRITE(10,*)' LIABILITY STREAM USED  ',LIANAME
      WRITE(10,*)
      WRITE(10,*)'       START END  SPAN'
      WRITE(10,*)'NUMBER WGHT  WGHT SENSIT SIC IDC  TICK',
     &           'SECURITY NAME'
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```
      WRITE(10,*)

C  ******    CALCULATE THE PORTFOLIO RETURNS    **********************
C  ******    FIRST CALCULATE RETURNS FOR NSTAT PERIOD ***************
      DO 800 I = 1,NSTAT
          PRET(I) = 0.0
          DO 900 J = 1,NUM
              PRET(I) = PRET(I) + RET(I,J)*X(J)
 900      CONTINUE
 800  CONTINUE
C  ******    NOW CALCULATE RETURNS AND WEIGHTS IN SIMULATION PERIOD *
      DO 801 I=1,NSIMS
          PRET(I+NSTAT)=0.0
          DO 901 J=1,NUM
              PRET(I+NSTAT) = PRET(I+NSTAT)+CUM(J)*RET(I+NSTAT,J)
 901      CONTINUE
          DO 1001 K = 1,NUM
              CUM(K) = CUM(K)*(1.+RET(I+NSTAT,K))/(1.+PRET(I+NSTAT))
1001      CONTINUE
 801  CONTINUE

C ***  WRITE OUT THE NEW WEIGHTS TO A FILE CALLED 'OLD'********
      OPEN(15,FILE = 'OLD', STATUS = 'OLD')
      REWIND(15)
      DO 140 I = 1,NUM
      WRITE(15,940) CUM(I)*100
140   CONTINUE
940   FORMAT(1X,F15.8)
      CLOSE(15)

C  ******    CALCULATE PARTIALS AND WRITE OUTPUT  ******************
      XVAR=0.0
      XRET = 0.0
      ICOUNT=0

      DO 131 I=1,NUM
          C(I,1)=-B(I)
          DO 132 J=1,NUM
              C(I,1)=C(I,1)+X(J)*A(I,J)*2
              XVAR=XVAR+X(I)*X(J)*A(I,J)
132       CONTINUE

          ICOUNT=ICOUNT+1
          IF(I.GT.NSTOCKS)ICOUNT=I

          WRITE(10,16)ICOUNT,X(I)*100,CUM(I)*100,C(I,1)*100,
     &                ISIC(I),IDC(I),NAME(I)

          XRETI = AVE(I) + UANIM
          XRET = XRET + X(I)*XRETI
131   CONTINUE
16    FORMAT(1X,I4,1X,2F6.3,F7.3,I4,1X,A9,1X,A36)

      WRITE(10,*)

      STD=(XVAR*12)**(0.5)*100
      XRET = XRET*12.0*100.0

      WRITE(10,649) STD, XRET
649   FORMAT(1X,' MINIMUM STD DEV =',F10.4,'  EXPECTED RETURN =',F10.4)
      WRITE(10,*)

C      IF(ITYPE.EQ.1.AND.XTOT.LT..995)WRITE(10,*)' ERROR ****** ',
C     .' SUM OF X S = %',XTOT*100.
C      IF(ITYPE.EQ.1.AND.XTOT.GT.1.005)WRITE(10,*)' ERROR ****** ',
C     .' SUM OF X S = %',XTOT*100.

      RETURN

      END
C                       END OF SUBROUTINE PORT
C   ***********************************************************************

C   ***********************************************************************
      SUBROUTINE TRACKER (NUM,IREAD)
C   ***********************************************************************
      INCLUDE 'COMMON.F'


C ******      SET AVERAGES AND COVARIANCES TO ZERO  ******************
      DO 400 I=1,3
          AVE(I)=0.0
          DO 400 J=1,3
              COV(I,J)=0.0
 400  CONTINUE

C ***  SET STAT ARRAY  1 = LIABILITY, 2 = PORTFOLIO, 3 = DIFFERENCES **
      DO 250 I=1,IREAD
          STAT(I,1)=ANIM(I)
          STAT(I,2)=PRET(I)
          STAT(I,3)=(PRET(I)-ANIM(I))
 250  CONTINUE


C *****       GO AROUND STATISTICS IF NSIM < 3
       IF(NSIMS.LT.3)GOTO 318

C *****       CALCULATE AVERAGES       **********************************
C *****       SET NSIM TO 2 FOR  STATISTICS IF NSIMS.LT.1    *********
      NSIM = NSIMS
      IF(NSIMS.LT.1) NSIM = 2
      DO 260 I=NSTAT+1,IREAD
          AVE(I)=AVE(I)+ANIM(I)/DBLE(NSIM)
```

```
          AVE(2)=AVE(2)+PRET(I)/DBLE(NSIM)
          AVE(3)=AVE(3)+(PRET(I)-ANIM(I))/DBLE(NSIM)
 260   CONTINUE

C *****       CALCULATE COVARIANCES  ***********************************

       DO 950 I=1,3
          VAR(I)=0.0
          DO 950 K=NSTAT+1,IREAD
             VAR(I)=VAR(I)+(STAT(K,I)-AVE(I))**2/DBLE(NSIM-1)
 950   CONTINUE


C ******    CALCULATE THE COVARIANCE MATRIX'S UPPER OFF DIAGONAL ****

          DO 960 I=1,3
            DO 960 J=I,3
              DO 828 K=NSTAT+1,IREAD
               COV(I,J)=COV(I,J)+((STAT(K,I)-AVE(I))*(STAT(K,J)-AVE(J)))
 828          CONTINUE
              COV(I,J)=COV(I,J)/DBLE(NSIM-1)
               COV(J,I) = COV(I,J)
 960       CONTINUE

C *****       CALCULATE CORRELATIONS       ******************************

      DO 951 I=1,3
          DO 951 J=1,I
          IF(VAR(I).LE. 0.0 .OR. VAR(J).LE. 0.0) GO TO 951
           COREL(I,J)=COV(I,J)/(VAR(I)**.5*VAR(J)**.5)
 951  CONTINUE
C *****       CALCULATE CUMULATIVE RETURNS     *************************
      PRET(NSTAT)=100
      ANIM(NSTAT)=100
      DO 569 I=NSTAT+1,IREAD
          XX=PRET(I)
          YY=ANIM(I)
          PRET(I)=PRET(I-1)*(1+XX)
          ANIM(I)=ANIM(I-1)*(1+YY)
 569  CONTINUE

       IF(VAR(1).NE. 0.0)   BETA = COV(1,2)/VAR(1)
       ALPHA = AVE(2) - BETA*AVE(1)

       SST =    0.0
       SSE =    0.0
       DO 952 I = NSTAT+1,IREAD
          SSE = SSE + (ALPHA+BETA*STAT(I,1)-STAT(I,2))**2
          SST = SST + (STAT(I,2)-AVE(2))**2
 952   CONTINUE

       IF(NSIMS.GT.2) STDERR = (SSE/DBLE(NSIMS-2))**.5
       IF(SST.NE.0.0) RSQ = 1 - SSE/SST

C*********************************************************************
C *****       BEGIN WRITING THE TRACKER OUTPUT     *********************

 318   WRITE(10,*)' TRACKER OUTPUT FILE '
       WRITE(10,*)
       WRITE(10,*)'   MONTH      LIA        PORT        DIF'
       WRITE(10,*)

C *****       WRITE MONTH, LIABILITY RET, PORTFOLIO RET, DIFFERENCE ****
       DO 700 I=NSTAT+I,IREAD
          ISTAT = I-(NSTAT+1)
          WRITE(10,612)ISTAT+NM,(STAT(I,J),J=1,3)
 612      FORMAT(1X,3X,I4,3F13.10)
 700   CONTINUE

C *****       WRITE CUMULATIVE RETURNS     ******************************

       WRITE(10,*)
        WRITE(10,886)
 886   FORMAT(1X,'CUMMULATIVE VALUES OF LIABILITIES AND ASSETS'/,
      ./,' MONTH    LIABILTIES      PORTFOLIO',/)

       DO 847 I=NSTAT,IREAD
          ISTAT = I-NSTAT-1
          WRITE(10,328)ISTAT+NM,ANIM(I),PRET(I)
 328      FORMAT(1X,I5,7X,F7.3,10X,F7.3)
 847   CONTINUE
 837   CONTINUE

C *****       WRITE STATISTICS  BASED ON SIMULATIONS MONTHS  ************

       WRITE(10,*)
        WRITE(10,*)'**********      STATISTICAL SUMMARY     **********'
        WRITE(10,985)NM,NM+NSIMS-1
 985   FORMAT(/,'     STATISTICS BASED ON MONTHS ',I4,' THROUGH',I4)


C *****       WRITE ALPHA,BETA,STDERR,CORREL,AND R-SQUARED   ************

        WRITE(10,*)
        WRITE(10,987)'ALPHA',ALPHA,'ANNUAL',ALPHA*1200
        WRITE(10,989)'BETA',BETA
        WRITE(10,988)'STD ERR',STDERR,STDERR*100
        WRITE(10,989)'CORRELATION',COREL(2,1)
        WRITE(10,988)'R-SQUARED',RSQ,RSQ*100
 987    FORMAT(1X,A12,10X,F10.6,A8,F10.2,' %')
 988    FORMAT(1X,A12,10X,F10.6,8X,F10.2,' %')
 989    FORMAT(1X,A12,10X,F10.6)
```

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```
C ******      WRITE AVERAGES AND VARIANCES OF 1-LIAB, 2-PORT, 3-DIFFS **
      WRITE(10,*)
      WRITE(10,*)
      WRITE(10,*)'ANNUAL RETURNS:              MEAN                STD DEV
      WRITE(10,*)

       DO 990 I = 1,3
          AVE(I) = (AVE(I)*12)*100
          VAR(I) = ((VAR(I)*12)**.5)*100
990    CONTINUE

       WRITE(10,916) 'LIABILITY',AVE(1),VAR(1)
       WRITE(10,916) 'PORTFOLIO',AVE(2),VAR(2)
       WRITE(10,916) 'DIFFERENCE',AVE(3),VAR(3)
916    FORMAT(1X,3X,A11,9X,F9.2,' %',10X,F9.2,' %')

C ******      WRITE PARAMETERS FOR THE RUN   ****************************
      WRITE(10,*)
      WRITE(10,*)
      WRITE(10,*)'      PARAMETERS FOR THIS RUN WERE: '
      WRITE(10,*)
      WRITE(10,101) TITLE
      WRITE(10,102) FILEOUT
      WRITE(10,103) LIABIN
      WRITE(10,104) STOCKIN
      WRITE(10,105) BONDIN
      WRITE(10,106) NMSAVE
      WRITE(10,107) NSIMS
      WRITE(10,108) NSTOCKS
      WRITE(10,109) NBONDS
      WRITE(10,110) IDUMMY
      WRITE(10,111) STOCKMIN
      WRITE(10,112) YIMAX
      WRITE(10,113) SMAX
      WRITE(10,114) NSTAT
      WRITE(10,115) NRETS
      WRITE(10,116) BULL1
      WRITE(10,117) TARG1
      WRITE(10,118) TURN1

101   FORMAT(1X,' 1) SPANNING RUN TITLE          ',A30)
102   FORMAT(1X,' 2) OUTPUT FILENAME             ',A30)
103   FORMAT(1X,' 3) LIABILITY STREAM FILE       ',A30)
104   FORMAT(1X,' 4) STOCK RETURN FILE           ',A30)
105   FORMAT(1X,' 5) BOND RETURN FILE            ',A30)
106   FORMAT(1X,' 6) MONTH SIMULATION BEGINS     ',I6)
107   FORMAT(1X,' 7) NUMBER OF MONTHS SIMULATED  ',I6)
108   FORMAT(1X,' 8) NUMBER OF STOCKS            ',I6)
109   FORMAT(1X,' 9) NUMBER OF BONDS             ',I6)
110   FORMAT(1X,'10) STOCKS TO READ PAST         ',I6)
111   FORMAT(1X,'11) MINIMUM STOCK HOLDING    % ',F6.2)
112   FORMAT(1X,'12) MAXIMUM INDUSTRY HOLDING % ',F6.2)
113   FORMAT(1X,'13) MAXIMUM STOCK HOLDING    % ',F6.2)
114   FORMAT(1X,'14) NSTAT                      ',I6)
115   FORMAT(1X,'15) NRETS                      ',I6)
116   FORMAT(1X,'16) BULLET                     ',F6.2)
117   FORMAT(1X,'17) TARGET                     ',F6.2)
118   FORMAT(1X,'18) TURNOVER FACTOR            ',F6.2)

C ******      WRITE HISTORICAL DATA USED TO MAKE RUN   ******************
      WRITE(10,*)
      WRITE(10,*)' PORTFOLIO CONSTRUCTED UPON THE FOLLOWING DATA:'
      WRITE(10,*)
      WRITE(10,*)'   MONTH      LIA        PORT        DIF'
      WRITE(10,*)
      DO 300 I=1,NSTAT
         WRITE(10,612)I+NM-(NSTAT+1),(STAT(I,J),J=1,3)
300   CONTINUE

      RETURN

      END
C                              END OF SUBROUTINE TRACKER
C   ***************************************************************************
C   ***************************************************************************
      SUBROUTINE BAL (NUM)
C   ***************************************************************************
      INCLUDE 'COMMON.F'
      DIMENSION CC(ND,2)
      INTEGER BUY(ND),SELL(ND)

      VNEW = 0.0
      VOLD = 0.0

      DO 10 I=1,NUM
         CC(I,1) = 0.0
         CC(I,2) = 0.0
         DO 20 J=1,NUM
            CC(I,1) = CC(I,1)+X(J)*A(I,J)*2.
            VNEW = VNEW+X(I)*X(J)*A(I,J)
            CC(I,2) = CC(I,2)+OLDWT(J)*A(I,J)*2.
            VOLD = VOLD+OLDWT(I)*OLDWT(J)*A(I,J)
20       CONTINUE
10    CONTINUE
C ********      DELTA IS THE PERCENTAGE IMPROVEMENT IN VARIANCE *******
      DELTA = (VOLD - VNEW)/VNEW
      DELTA = DELTA * 10000.
C ******** IF THE OLD VARIANCE IS ZERO USE THE NEW PARTIALS TO SORT **
      KVAR = 2
      IF (VOLD.EQ.0) KVAR = 1

      IBUY = 0
```

```
      ISELL = 0
      TURNOV = 0.0

      DO 30 I = 1,NUM
         IF((X(I)-OLDWT(I)).GT.0.001) THEN
           IBUY = IBUY + 1
           BUY(IBUY) = I
         ELSE IF((X(I)-OLDWT(I)).LT.-0.001) THEN
           ISELL = ISELL +1
           SELL(ISELL) = I
         END IF
         TURNOV = TURNOV + ABS(X(I)-OLDWT(I))
30    CONTINUE

C ******  SORT BASED ON PARTIALS ***************************************
C ******      SORT THE BUYS     ***************************************
      DO 40 I = 1,IBUY-1
         DO 50 J = I+1,IBUY
         IF( CC(BUY(J),KVAR).LT.CC(BUY(I),KVAR)) THEN
           ITEMP = BUY(I)
           BUY(I) = BUY(J)
           BUY(J) = ITEMP
         END IF
50       CONTINUE
40    CONTINUE
C ******      SORT THE SELLS    ***************************************
      DO 60 I = 1,ISELL-1
         DO 70 J = I+1,ISELL
      TEST = CC(SELL(J),KVAR) - CC(SELL(I),KVAR)
         IF (TEST .GT. 0) THEN
           ITEMP = SELL(I)
           SELL(I) = SELL(J)
           SELL(J) = ITEMP
         END IF
70       CONTINUE

60    CONTINUE

      WRITE(10,*)
      WRITE(10,*)'                    TURNOVER = ',TURNOV*50,' %'
      WRITE(10,*)
      WRITE(10,*)'VARIANCE AT  OLD  WEIGHTS = ',VOLD*10000
      WRITE(10,*)'VARIANCE AT  NEW  WEIGHTS = ',VNEW*10000
      WRITE(10,*)'                    DELTA = ',DELTA/100,' %'
      WRITE(10,*)
      WRITE(10,*)

C ************          WRITE THE BUYS       *********************

      WRITE(10,*)'                                  ***    BUY    ***'
      WRITE(10,102)('*',I=1,78)
      WRITE(10,*)'    ***  WEIGHTS ***  SPAN   SIC',
     &           '    SYMBOL    SECURITY'
      WRITE(10,*)'    OLD   NEW  DELTA  SENSIT CODE',
     &           '  IDC TICK   NAME'
      WRITE(10,102)('*',I=1,78)

      DO 80 I = 1,IBUY
      XOLD = OLDWT(BUY(I))*100
      XNEW = X(BUY(I))*100
      WRITE(10,101) XOLD,XNEW,XNEW-XOLD,CC(BUY(I),KVAR)*1000,
     &              ISIC(BUY(I)),IDC(BUY(I)),NAME(BUY(I))
80    CONTINUE

      WRITE(10,*)
      WRITE(10,*)
      WRITE(10,*)
C ************          WRITE THE SELLS      *********************
      WRITE(10,*)'                                  ***    SELL    ***'
      WRITE(10,102)('*',I=1,78)
      WRITE(10,*)'    ***  WEIGHTS ***  SPAN   SIC',
     &           '    SYMBOL    SECURITY'
      WRITE(10,*)'    OLD   NEW  DELTA  SENSIT CODE',
     &           '  IDC TICK   NAME'
      WRITE(10,102)('*',I=1,78)

      DO 90 I = 1,ISELL
      XOLD = OLDWT(SELL(I))*100
      XNEW = X(SELL(I))*100
      WRITE(10,101) XOLD,XNEW,XNEW-XOLD,CC(SELL(I),KVAR)*1000,
     &              ISIC(SELL(I)),IDC(SELL(I)),NAME(SELL(I))
90    CONTINUE

101   FORMAT(1X,4F7.3,I4,4X,A9,2X,A30)
102   FORMAT(1X,80A1)

C *******   WRITE OUT THE  INDUSTRY  WEIGHTS   ************************
      CALL INDUST
      WRITE(10,*)
      WRITE(10,*)
      WRITE(10,*)'          *** INDUSTRY WEIGHTINGS ***'
      WRITE(10,102)('*',I=1,78)
      WRITE(10,*)' CODE              INDUSTRY                WEIGHT'
      WRITE(10,102)('*',I=1,78)

      DO 133 I = 1,99
         CUM(I) = 0.0
         DO 134 J = 1,NUM
           IF (ISIC(J).EQ.I) CUM(I) = CUM(I) + X(J)
134      CONTINUE
         IF (CUM(I).GT. 0.001) THEN
           WRITE(10,135) I,SIC(I),CUM(I)*100.
         END IF
133   CONTINUE
```

```
      SIC(38) = 'MEAS. ANAL. & CONT. INST. ETC.'
      SIC(39) = 'MISC. MANUFACTURING IND.'
      SIC(40) = 'RAILROAD TRANS.'
      SIC(41) = 'LOC. AND SUB. TRANS. & HPT'
      SIC(42) = 'MOTOR FREIGHT TRANS. AND WARE.'
      SIC(43) = 'U.S. POSTAL SERVICE'
      SIC(44) = 'WATER TRANSPORTATION'
      SIC(45) = 'TRANSPORTATION BY AIR'
      SIC(46) = 'PIPE LINES EX. NATURAL GAS'
      SIC(47) = 'TRANSPORTATION SERVICES'
      SIC(48) = 'COMMUNICATION'
      SIC(49) = 'ELECTRIC GAS AND SANIT. SERV.'
      SIC(50) = 'WHOLESALE TRADE-DURABLE GOODS'
      SIC(51) = 'WHOLESALE TRADE-NONDUR. GOODS'
      SIC(52) = 'BUILDING MAT. HARD. GAR. SUPP.'
      SIC(53) = 'GENERAL MERCH. STORES'
      SIC(54) = 'FOOD STORES'
      SIC(55) = 'AUTOMOTIVE DEAL AND GAS. SS'
      SIC(56) = 'APPAREL AND ACCESS. STORES'
      SIC(57) = 'HOME FURN. AND EQUIP. STORES'
      SIC(58) = 'EATING AND DRINKING PLACES'
      SIC(59) = 'MISCELLANEOUS RETAIL'
      SIC(60) = 'BANKING'
      SIC(61) = 'CRED. AGEN. OTH. THAN BANKS.'
      SIC(62) = 'SEC. AND COMM. BROK. DEEXSE'
      SIC(63) = 'INSURANCE CARRIERS'
      SIC(64) = 'INS. AGENTS BROK. SERV.'
      SIC(65) = 'REAL ESTATE'
      SIC(66) = 'COMB. RE INS. LOANS & LAW OFF.'
      SIC(67) = 'HOLD. AND OTHER INV. COMP.'
      SIC(70) = 'HOTELS ROOM. HOUSES CAMP AOLP'
      SIC(72) = 'PERSONAL SERVICES'
      SIC(73) = 'BUSINESS SERVICES'
      SIC(75) = 'AUTO. REPAIR SERV. AND GAR.'
      SIC(76) = 'MISC. REPAIR SERVICES'
      SIC(78) = 'MOTION PICTURES'
      SIC(79) = 'AMUSE. AND REC. SERV. EX. MP'
      SIC(80) = 'HEALTH SERVICES'
      SIC(81) = 'LEGAL SERVICES'
      SIC(82) = 'EDUCATIONAL SERVICES'
      SIC(83) = 'SOCIAL SERVICES'
      SIC(84) = 'MUSEUM ART GALL. BOT. Z.G.'
      SIC(86) = 'NONPROFIT MEM. ORGAN.'
      SIC(89) = 'MISCELLANEOUS SERVICES'
      SIC(91) = 'EXEC. LEG. & GOVT EX. FIN.'
      SIC(92) = 'JUSTICE PUBLIC SAFETY'
      SIC(93) = 'PUB. FIN. TAX. & MON. POLICY'
      SIC(94) = 'ADMIN. OF HUMAN RES. PROGRAMS'
      SIC(95) = 'ADMIN. OF QUAL. & HOUS. PROG.'
      SIC(96) = 'ADMIN. OF ECONOMIC PROGRAMS'
      SIC(97) = 'NATIONAL SEC. & INTL AFFAIRS'
      SIC(99) = 'NONCLASSIFIABLE ESTABLISHMENTS'

  135 FORMAT(1X,I5,3X,A30,F10.2,' %')

      SUMWGHT = 0.0
      DO 136 I = 1,NUM
        SUMWGHT = SUMWGHT + X(I)
  136 CONTINUE
      WRITE(10,137)'                    TOTAL   =   ' ,SUMWGHT*100
  137 FORMAT(1X,A38,F10.2,' %')

      ENDFILE(10)
      CLOSE(10)
      RETURN
      END
C*****************     END OF SUBROUTINE  BAL       *****************
C   ***************************************************************************
      SUBROUTINE INDUST
C   ***************************************************************************

      INCLUDE 'COMMON.F'

      SIC(1) = 'AGRICULTURAL PRODUCTION-CROPS'
      SIC(2) = 'AGRICULTURAL PROD.-LIVESTOCK'
      SIC(7) = 'AGRICULTURAL SERVICES'
      SIC(8) = 'FORESTRY'
      SIC(9) = 'FISHING HUNTING AND TRAPPING'
      SIC(10) = 'METAL MINING'
      SIC(11) = 'ANTHRACITE MINING'
      SIC(12) = 'BITUMINOUS COAL & LIGNITE MIN.'
      SIC(13) = 'OIL & GAS EXTRACTION'
      SIC(14) = 'MIN. & QUARRY. OF NONMET. MIN.'
      SIC(15) = 'BUILD. CONST.-G. C. & O. B.'
      SIC(16) = 'CONST. OTH THAN B.C.-G.C.'
      SIC(17) = 'CONST.-SPEC. TRADE CONT.'
      SIC(20) = 'FOOD KINDRED PRODUCTS'
      SIC(21) = 'TOBACCO MANUFACTURERS'
      SIC(22) = 'TEXTILE MILL PRODUCTS'
      SIC(23) = 'APP. & OTH. FIN. PROD. MFFAOSM'
      SIC(24) = 'LUMBER & WOOD PROD. EX. FURN.'
      SIC(25) = 'FURNITURE AND FIXTURES'
      SIC(26) = 'PAPER AND ALLIED PRODUCTS'
      SIC(27) = 'PRINTING PUBLISHING AND A.P.'
      SIC(28) = 'CHEMICAL AND ALLIED PROD.'
      SIC(29) = 'PETROLEUM REFIN. & REL. PROD.'
      SIC(30) = 'RUBBER AND MISC. PLAST. PROD.'
      SIC(31) = 'LEATHER & LEATHER PRODUCTS'
      SIC(32) = 'STONE CLAY GLASS & CONC. PROD.'
      SIC(33) = 'PRIMARY METAL INDUSTRIES'
      SIC(34) = 'FAB. METAL PROD. EX. M.&T.E.'
      SIC(35) = 'MACHINERY EXCEPT ELECTRICAL'
      SIC(36) = 'ELE. AND ELE. MACH.'
      SIC(37) = 'TRANSPORTATIONS EQUIPMENT'
```

```
C       BONDIN          - BOND RETURNS FILE
C       NMSAVE          - FIRST MONTH OF SIMULATION
C       NSIMS           - NUMBER OF MONTHS TO SIMULATE
C       NSTOCKS         - NUMBER OF STOCK TO SEND TO OPTIMIZER
C       NBONDS          - NUMBER OF BONDS TO SEND TO OPTIMIZER
C       IDUMMY          - NUMBER OF STOCKS TO READ PAST IN STOCKIN
C       STOCKMIN        - MINIMUM HOLDING IN STOCKS
C       YIMAX           - INDUSTRY MAXIMUM HOLDING
C       SMAX            - SECURITY MAXIMUM HOLDING
C       BULLIT          - CLIMBING FACTOR
C       TARGIT          - ADJUSTMENT FACTOR FOR TARGET
C       TURN            - TURNOVER FACTOR
      INCLUDE 'COMMON.F'

      PARAMETER (MAXTXT = 50,LINES = 24)

      CHARACTER HEAD*(MAXTXT),LAST*(MAXTXT),OPTIONS(LINES)*(MAXTXT)
      CHARACTER*30 PAST
* **
* **      INITIALIZE READ IN FILE: PAST  =  'PAST.DAT'

      PAST = 'PAST.DAT'
      WRITE(*,100)(' ',I = 1,5)
      WRITE(*,*)'   READING PAST DATA.....'
      WRITE(*,100)(' ',I = 1,5)

5     OPEN(8,FILE = PAST, STATUS = 'OLD', ERR = 10)
      READ(8,101)TITLE
      READ(8,101)FILEOUT
      READ(8,101)LIABIN
      READ(8,101)STOCKIN
      READ(8,101)BONDIN
      READ(8,102)NMSAVE
      READ(8,102)NSIMS
      READ(8,102)NSTOCKS
      READ(8,102)NBONDS
      READ(8,102)IDUMMY
      READ(8,103)STOCKMIN
      READ(8,103)YIMAX
      CLOSE(8)
      RETURN

10    CONTINUE

* **      GIVE OPTION TO READ FROM SCREEN WITHOUT DUMPING OUT OF
* **      PROGRAM OR TO READ FROM DIFFERENT FILE NAME

      HEAD = '... WARNING: THE PAST DATA FILE DOES NOT EXIST'
      LAST = '                              ( CTRL-C TO ABORT )'
      NBROPT = 2
      OPTIONS(1) = 'INPUT NEW NAME FOR PAST DATA FILE'
      OPTIONS(2) = 'READ IN NEW DATA FROM SCREEN '

      RETURN
      END
C*****************     END OF SUBROUTINE  INDUST     ******************
C  UPDATED December 6, 1988
*************************************************************************
      SUBROUTINE INTRO
*************************************************************************
* **
* **   THIS ROUTINE INTRODUCES THE SPANNING PROGRAM AND
* **   ASKS FOR SCREEN OR FILE INPUT OPTION
* **
      INCLUDE 'COMMON.F'

      INTEGER RESPON

      PARAMETER (MAXTXT = 60,LINES = 24)
      CHARACTER HEAD*(MAXTXT),LAST*(MAXTXT),OPTION(LINES)*(MAXTXT)

      HEAD = '      WELCOME  TO  THE  NISA  SPANNING  OPTIMIZER'

      NBROPT = 2
      OPTION(1) = 'SINGLE RUN WITH WEIGHTS IN FILE: OLD'
      OPTION(2) = 'UPDATE RUN WITH WEIGHTS CALCUATED FROM HOLDINGS'

      LAST = ' '

10    CALL MENU(LINES,HEAD,LAST,NBROPT,OPTION,RESPON)

      IF (RESPON.EQ.1) THEN
         IHOLD = 0
         CALL REDPAST

      ELSE IF (RESPON.EQ.2) THEN
         IHOLD = 1
         CALL REDPAST

      ELSE
         WRITE(*,*)'NO OPTION SELECTED - PLEASE TRY AGAIN'
         GO TO 10

      END IF

C     RETURN
      END
******************     END OF SUBROUTINE  INTRO      ******************
*************************************************************
      SUBROUTINE REDPAST
*************************************************************
C     TITLE           - TITLE FOR THIS RUN
C     FILEOUT         - OUTPUT FILE
C     LIABIN          - LIABILITY RETURNS FILE
C     STOCKIN         - STOCK RETURNS FILE
```

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```
 20     CALL MENU (LINES,HEAD,LAST,NBROPT,OPTIONS,IRESPON)

        IF ( IRESPON.EQ.1) THEN
           WRITE(*,100)(' ',I = 1,5)
           WRITE(*,104)
           READ(*,'(A30)',END = 20,ERR = 20) PAST
           GO TO 5

        ELSE IF (IRESPON.EQ.2) THEN
           CALL REDSCRN
           RETURN

        END IF

        RETURN

 100    FORMAT('0',A1)
 101    FORMAT(A35)
 102    FORMAT(I4)
 103    FORMAT(F7.2)
 104    FORMAT(' NAME FOR PAST DATA FILE --- ',$)

        END

*******************     END OF SUBROUTINE  REDPAST     ******************

**********************************************************************
      SUBROUTINE REDSCRN
**********************************************************************

C       TITLE           - TITLE FOR THIS RUN
C       FILEOUT         - OUTPUT FILE
C       LIABIN          - LIABILITY RETURNS FILE
C       STOCKIN         - STOCK RETURNS FILE
C       BONDIN          - BOND RETURNS FILE
C       NMSAVE          - FIRST MONTH OF SIMULATION
C       NSIMS           - NUMBER OF MONTHS TO SIMULATE
C       NSTOCKS         - NUMBER OF STOCK TO SEND TO OPTIMIZER
C       NBONDS          - NUMBER OF BONDS TO SEND TO OPTIMIZER
C       IDUMMY          - NUMBER OF STOCKS TO READ PAST IN STOCKIN
C       STOCKMIN        - MINIMUM HOLDING IN STOCKS
C       YMAX            - INDUSTRY MAXIMUM HOLDING

      INCLUDE 'COMMON.F'

* **       DEFAULT NAMES FOR STOCK AND BOND FILES
* **       STOCKS.PRN      &   BONDS.PRN

      WRITE(*,113)(' ',I = 1,12)

 113    FORMAT('0',A1)

 1      WRITE(*,101)
 101    FORMAT(' 1) ENTER TITLE FOR SPANNING RUN        - ',$)
        READ(*,'(A30)',END = 1,ERR = 1) TITLE
        WRITE(*,*)

 2      WRITE(*,102)
 102    FORMAT(' 2) ENTER OUTPUT FILE NAME              - ',$)
        READ(*,'(A30)',END = 2,ERR = 2) FILEOUT
        WRITE(*,*)

 3      WRITE(*,103)
 103    FORMAT(' 3) ENTER LIABILITY RETURNS FILE NAME   - ',$)
        READ(*,'(A30)',END = 3,ERR = 3) LIABIN
        WRITE(*,*)

 4      WRITE(*,104)
 104    FORMAT(' 4) ENTER STOCK RETURNS FILE NAME       - ',$)
        READ(*,'(A30)',END = 4,ERR = 4) STOCKIN
        IF (STOCKIN.EQ.' ')STOCKIN = 'STOCKS.PRN'
        WRITE(*,*)

 5      WRITE(*,105)
 105    FORMAT(' 5) ENTER BOND RETURNS FILE NAME        - ',$)
        READ(*,'(A30)',END = 5,ERR = 5) BONDIN
        IF (BONDIN.EQ.' ')BONDIN = 'BONDS.PRN'
        WRITE(*,*)

 6      WRITE(*,*)' 6) ENTER YEAR AND MONTH TO BEGIN
        WRITE(*,106)
 106    FORMAT('    SIMULATION (e.g. FEB 1987 = 8702)   - ',$)
        READ(*,*,END = 6,ERR = 6) NMSAVE
        WRITE(*,*)

 7      WRITE(*,107)
 107    FORMAT(' 7) ENTER NUMBER OF MONTHS TO SIMULATE - ',$)
        READ(*,*,END = 7,ERR = 7) NSIMS
        WRITE(*,*)

 8      WRITE(*,108)
 108    FORMAT(' 8) ENTER NUMBER OF  STOCKS  TO USE     - ',$)
        READ(*,*,END = 8,ERR = 8) NSTOCKS
        WRITE(*,*)

 9      WRITE(*,109)
 109    FORMAT(' 9) ENTER NUMBER OF  BONDS  TO USE      - ',$)
        READ(*,*,END = 9,ERR = 9) NBONDS
        WRITE(*,*)

 10     WRITE(*,110)
 110    FORMAT('10) ENTER NUMBER OF STOCKS READ PAST    - ',$)
```

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```
      ELSE IF (IRESPON.EQ.4) THEN
204      WRITE(*,124)
         READ(*,'(A30)',END = 204, ERR = 204) STOCKIN

      ELSE IF (IRESPON.EQ.5) THEN
205      WRITE(*,125)
         READ(*,'(A30)',END = 205, ERR = 205) BONDIN

      ELSE IF (IRESPON.EQ.6) THEN
206      WRITE(*,126)
         READ(*,*,END = 206, ERR = 206) NMSAVE

      ELSE IF (IRESPON.EQ.7) THEN
207      WRITE(*,127)
         READ(*,*,END = 207, ERR = 207) NSIMS

      ELSE IF (IRESPON.EQ.8) THEN
208      WRITE(*,128)
         READ(*,*,END = 208, ERR = 208) NSTOCKS

      ELSE IF (IRESPON.EQ.9) THEN
209      WRITE(*,129)
         READ(*,*,END = 209, ERR = 209) NBONDS

      ELSE IF (IRESPON.EQ.10) THEN
210      WRITE(*,130)
         READ(*,*,END = 210, ERR = 210) IDUMMY

      ELSE IF (IRESPON.EQ.11) THEN
211      WRITE(*,131)
         READ(*,*,END = 211, ERR = 211) STOCKMIN

      ELSE IF (IRESPON.EQ.12) THEN
212      WRITE(*,132)
         READ(*,*,END = 212, ERR = 212) YIMAX

      ELSE IF (IRESPON.EQ.13) THEN
213      WRITE(*,133)
         READ(*,*,END = 213, ERR = 213) SMAX

      ELSE IF (IRESPON.EQ.14) THEN
214      WRITE(*,134)
         READ(*,*,END = 214, ERR = 214) NSTAT

      ELSE IF (IRESPON.EQ.15) THEN
215      WRITE(*,135)
         READ(*,*,END = 215, ERR = 215) NRETS

      ELSE IF (IRESPON.EQ.16) THEN
216      WRITE(*,136)
         READ(*,*,END = 216, ERR = 216) BULLET

         READ(*,*,END =10,ERR = 10) IDUMMY
         WRITE(*,*)

11    WRITE(*,111)
111   FORMAT('11) ENTER MINIMUM STOCK HOLDING       - % ',$)
      READ(*,*,END = 11,ERR = 11) STOCKMIN
      WRITE(*,*)

12    WRITE(*,112)
112   FORMAT('12) ENTER MAXIMUM INDUSTRY HOLDING    - % ' ,$)
      READ(*,*,END = 12,ERR = 12) YIMAX
      WRITE(*,*)

      RETURN

100   FORMAT(A35)

      END
*****************     END OF SUBROUTINE  REDSCRN    *****************

*************************************************************************
      SUBROUTINE MODIFY
*************************************************************************
* **
* **   THIS ROUTINE MODIFIES THE INPUT DATA IF NECESSARY
* **

      INCLUDE 'COMMON.F'

10    WRITE(*,100)(' ',I = 1,5)

      WRITE(*,*)'********    CURRENTLY SELECTED PARAMETERS    ********'
******************   DISPLAY SELECTED PARAMETERS   ********************
      CALL DISPLAY
      IRESPON = 0
      WRITE(*,120)
      READ(*,'(I2)',END = 20,ERR = 10) IRESPON

      IF(IRESPON.EQ.0) THEN
         RETURN

      ELSE IF (IRESPON .EQ. 1 ) THEN
201      WRITE(*,121)
         READ(*,'(A30)',END = 201, ERR = 201) TITLE

      ELSE IF (IRESPON.EQ.2) THEN
202      WRITE(*,122)
         READ(*,'(A30)',END = 202, ERR = 202) FILEOUT

      ELSE IF (IRESPON.EQ.3) THEN
203      WRITE(*,123)
         READ(*,'(A30)',END = 203, ERR = 203) LIABIN
```

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```
      WRITE(*,105) BONDIN
      WRITE(*,106) NMSAVE
      WRITE(*,107) NSIMS
      WRITE(*,108) NSTOCKS
      WRITE(*,109) NBONDS
      WRITE(*,110) IDUMMY
      WRITE(*,111) STOCKMIN
      WRITE(*,112) YIMAX
      WRITE(*,113) SMAX
      WRITE(*,114) NSTAT
      WRITE(*,115) NRETS
      WRITE(*,116) BULLET
      WRITE(*,117) TARGET
      WRITE(*,118) TURN

      RETURN

100   FORMAT('0',A1)
101   FORMAT(1X,' 1) SPANNING RUN TITLE                    ',A30)
102   FORMAT(1X,' 2) OUTPUT FILENAME                       ',A30)
103   FORMAT(1X,' 3) LIABILITY STREAM FILE                 ',A30)
104   FORMAT(1X,' 4) STOCK RETURN FILE                     ',A30)
105   FORMAT(1X,' 5) BOND RETURN FILE                      ',A30)
106   FORMAT(1X,' 6) MONTH TO BEGIN SIMULATION             ',I6)
107   FORMAT(1X,' 7) NUMBER OF MONTHS TO SIMULATE          ',I6)
108   FORMAT(1X,' 8) NUMBER OF STOCKS                      ',I6)
109   FORMAT(1X,' 9) NUMBER OF BONDS                       ',I6)
110   FORMAT(1X,'10) STOCKS TO READ PAST                   ',I6)
111   FORMAT(1X,'11) MINIMUM STOCK HOLDING              %  ',F6.2)
112   FORMAT(1X,'12) MAXIMUM INDUSTRY HOLDING           %  ',F6.2)
113   FORMAT(1X,'13) MAXIMUM SINGLE STOCK HOLDING       %  ',F6.2)
114   FORMAT(1X,'14) NSTAT                                 ',I6)
115   FORMAT(1X,'15) NRETS                                 ',I6)
116   FORMAT(1X,'16) BULLET                                ',F6.2)
117   FORMAT(1X,'17) TARGET                                ',F6.2)
118   FORMAT(1X,'18) TURNOVER FACTOR                       ',F6.2)
      END
******************      END OF SUBROUTINE  DISPLAY     ******************

********************************************************************************
      SUBROUTINE SAVDAT
********************************************************************************
* **
* **    THIS ROUTINE SAVE THE FILE FOR LATER USE
* **

      INCLUDE 'COMMON.F'

C     WRITE(*,100)(' ',I = 1,7)
      WRITE(*,104)'    SAVING DATA TO FILE:  PAST.DAT  .......'
C     WRITE(*,100)(' ',I = 1,5)

      ELSE IF (IRESPON.EQ.17) THEN
217      WRITE(*,137)
         READ(*,*,END = 217, ERR = 217) TARGET

      ELSE IF (IRESPON.EQ.18) THEN
218      WRITE(*,138)
         READ(*,*,END = 218, ERR = 218) TURN

      END IF

      GO TO 10

20    RETURN

100   FORMAT('0',A1)
120   FORMAT('0',' ENTER NUMBER TO MODIFY   <ENTER> TO CONTINUE: ',$)
121   FORMAT('0',' ENTER SPANNING RUN TITLE                      ',$)
122   FORMAT('0',' ENTER FILENAME FOR OUTPUT                     ',$)
123   FORMAT('0',' ENTER LIABILITY STREAM FILE                   ',$)
124   FORMAT('0',' ENTER STOCK RETURN FILE                       ',$)
125   FORMAT('0',' ENTER BOND RETURN FILE                        ',$)
126   FORMAT('0',' ENTER MONTH TO BEGIN SIMULATION               ',$)
127   FORMAT('0',' ENTER NUMBER OF MONTHS TO SIMULATE            ',$)
128   FORMAT('0',' ENTER NUMBER OF STOCKS                        ',$)
129   FORMAT('0',' ENTER NUMBER OF BONDS                         ',$)
130   FORMAT('0',' ENTER STOCKS TO READ PAST                     ',$)
131   FORMAT('0',' ENTER MINIMUM TOTAL STOCK HOLDING          %  ',$)
132   FORMAT('0',' ENTER MAXIMUM INDUSTRY HOLDING             %  ',$)
133   FORMAT('0',' ENTER MAXIMUM SINGLE STOCK HOLDING         %  ',$)
134   FORMAT('0',' ENTER NSTAT                                   ',$)
135   FORMAT('0',' ENTER NRETS                                   ',$)
136   FORMAT('0',' ENTER BULLET                                  ',$)
137   FORMAT('0',' ENTER TARGET                                  ',$)
138   FORMAT('0',' ENTER TURNOVER FACTOR                         ',$)
      END
******************      END OF SUBROUTINE  MODIFY      ******************

********************************************************************************
      SUBROUTINE DISPLAY
********************************************************************************
* **
* **    THIS ROUTINE DISPLAYS SELECTED PARAMETERS FOR SPANNING RUN
* **

      INCLUDE 'COMMON.F'

      WRITE(*,100)
      WRITE(*,101) TITLE
      WRITE(*,102) FILEOUT
      WRITE(*,103) LIABIN
      WRITE(*,104) STOCKIN
```

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```
      INTEGER MAXTXT
      PARAMETER (MAXTXT = 50)
* **
* **   CALL SPECIFICATIONS
      CHARACTER OPTION(*)*(MAXTXT),HEADER*(MAXTXT),LAST*(MAXTXT)
      INTEGER NBROPT,RESPON,LINES
* **
* **   LOCAL SPECIFICATIONS
      INTEGER I,IMAX
* **
* **
* **   PRINT BLANK UPPER SCREEN
      IMAX = (LINES-NBROPT-7)/2+1
      IF (IMAX.LT.0) THEN
         WRITE(*,*)'TOO MANY OPTIONS TO FIT SCREEN SIZE'
         STOP
      END IF
 5    DO 10 I = 1,IMAX
 10   WRITE(*,*)' '
* **
* **   PRINT MENU
      WRITE(*,*)HEADER
      WRITE(*,*)' '

      DO 20 I = 1,NBROPT
      WRITE(*,'(1X,I2,2H) ,$)') I
      WRITE(*,*)OPTION(I)
20    CONTINUE

      WRITE(*,*) LAST
* **
* **   BLANK OUT REST OF SCREEN
      DO 25 I = 1,IMAX
25    WRITE(*,*)' '
* **
* **   REQUEST RESPONSE
      WRITE(*,*)' '
      WRITE(*,*)' '
30    WRITE(*,999)
999   FORMAT(' SELECT NUMBER OF OPTION ---> ',$)
* **   RESPONSE SET TO ZERO IN CASE OF CARRIAGE RETURN
      RESPON = 0
      READ (*,'(I2)',END = 40,ERR = 5) RESPON
      IF (RESPON.LT.0.OR.RESPON.GT.NBROPT) THEN
         WRITE(*,*)' OPTION OUT OF RANGE'
         GO TO 30
      END IF
40    RETURN
      END
C*********  *******     END OF SUBROUTINE  MENU      ******************
C  ********  ***************************************************************
      SUBROUTINE QUAD1 (A,KT,RHS,COST,QUAD,INPUT,TOL,TITLE,PFILE,
```

```
      OPEN(8,FILE = 'PAST.DAT',STATUS = 'OLD')
      WRITE(8,101)TITLE
      WRITE(8,101)FILEOUT
      WRITE(8,101)LIABIN
      WRITE(8,101)STOCKIN
      WRITE(8,101)BONDIN
      WRITE(8,102)NMSAVE
      WRITE(8,102)NSIMS
      WRITE(8,102)NSTOCKS
      WRITE(8,102)NBONDS
      WRITE(8,102)IDUMMY
      WRITE(8,103)STOCKMIN
      WRITE(8,103)YIMAX
      CLOSE (8)

      RETURN

100   FORMAT('0',A1)
101   FORMAT(A35)
102   FORMAT(I4)
103   FORMAT(F7.2)
104   FORMAT('+',A50)

      END

*****************     END OF SUBROUTINE  SAVDAT     *****************

C*************************************************************************
      SUBROUTINE MENU (LINES,HEADER,LAST,NBROPT,OPTION,RESPON)
C*************************************************************************

* **
* **   PURPOSE: TO PRINT A MENU AND READ RESPONSE
* **
* **
* **
* **   VARIABLE DEFINITIONS
* **   LINES        LINESIZE OF SCREEN
* **   HEADER       TITLE LINE FOR MENU
* **   LAST         LAST LINE OF MENU
* **   NBROPT       NUMBER OF OPTIONS
* **   OPTION       LIST OF OPTIONS
* **                DIMENSIONED OPTION(*)*(*) SO LENGTH
* **                OF CHARACTER STRINGS AND ARRAY SENT BY
* **                CALLING PROGRAM
* **   RESPON       NUMERIC RESPONSE
* **   I            MISCELLANEOUS INDEX
* **   IMAX         NUMBER OF BLANK LINES, TOP AND BOTTOM
* **
* **
* **   OVERALL SPECIFICATIONS
      IMPLICIT REAL (A-Z)
```

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```
C
C TOL    --- TOLERANCE VECTOR OF SIZE 2 CONTAINING...
C TZERO    1 ROUND-OFF OR ZERO TOLERANCE.  IF .LE. 0 RESET TO 1.E-7
C TPIV     2 PIVOT TOLERANCE.  IF .LE. 0 RESET TO 1.E-6
C
C TITLE  --- TITLE PRINTED IN OUTPUT.  TYPE CHARACTER.
C            MAY CONTAIN UP TO 64 CHARACTERS.
C            TRUNCATED TO 64 CHARACTERS IF LONGER.
C PFILE  --- FILE NAME QUADPR WRITES OUTPUT ONTO IF REQUESTED.
C            TYPE CHARACTER.  MAY CONTAIN UP TO 64 CHARACTERS.
C            IF FILE CANNOT BE OPENED, A FILE WILL BE CREATED
C            AND A MESSAGE PRINTED.  IF THE NAME IS ALL BLANKS,
C            OUTPUT TO BE FILED WILL BE DISCARDED.
C OBJ    --- OBJECTIVE VALUE.
C X      --- NO-VECTOR THAT WILL CONTAIN THE SOLUTION.
C RC     --- NO-VECTOR THAT WILL CONTAIN THE REDUCED COSTS.
C DUAL   --- MO-VECTOR THAT WILL CONTAIN THE DUAL SOLUTION.
C SLK    --- MO-VECTOR THAT WILL CONTAIN THE SLACK VALUES.
C IOUT   --- VECTOR OF SIZE 2, THAT WILL CONTAIN...
C IERR     1 STATUS CODE FROM 1 TO 6.
C            1 - SOLUTION IS OPTIMAL.
C            2 - NO SOLUTION.
C            3 - PIVOT LIMIT REACHED.
C            4 - INVALID QUAD MATRIX.
C            5 - PROBLEM DATA ERROR.
C            6 - ALGORITHM ERROR.
C ITCNT    2 NUMBER OF PIVOTS.
C
C WS     --- WORK SPACE ARRAY OF SIZE AT LEAST
C            2*(MO+NO)**2 + 12*(MO+NO) + 16 IF ANY EQUALITY CONSTRAINTS
C            ARE PRESENT OR  2*(MO+NO)**2 +  8*(MO+NO) + 6
C            IF ALL CONSTRAINTS ARE INEQUALITIES.
C
      IMPLICIT REAL (A-H,O-Z)

      DIMENSION A(1),KT(1),RHS(1),COST(1),QUAD(1),INPUT(1),
     1   TOL(1),X(1),RC(1),DUAL(1),SLK(1),IOUT(1),WS(1)
      CHARACTER*64  TITLE,PFILE
C
      INTEGER  ROW,COL,INDX,MORE,P,P1,PSQ
      COMMON /QPRCBI/ INPUTS(14),IOUTS(2),ROW,COL,INDX,MORE,P,P1,PSQ,
     1   CALL,LENREQ,IO1,IO2,IO3
      EQUIVALENCE (INPUTS(1),ML), (INPUTS(2),NL), (INPUTS(3),MO),
     1   (INPUTS(4),NO), (INPUTS(5),MINMAX), (INPUTS(6),LENWS),
     2   (INPUTS(7),MAXIT), (INPUTS(8),KOBJ), (INPUTS(9),JIT),
     3   (INPUTS(10),JDATA), (INPUTS(11),JPIVOT), (INPUTS(12),JSOL),
     4   (INPUTS(13),JOUT), (INPUTS(14),JWIDTH),
     5   (IOUTS(1),IERR), (IOUTS(2),ITCNT)
C
      COMMON /QPRCBR/ TOLS(2)
      EQUIVALENCE (TOLS(1),TZERO), (TOLS(2),TPIV)
C
     *   OBJ,X,RC,DUAL,SLK,IOUT,WS)
C
C          SUBROUTINE QUADPR FOR QUADRATIC PROGRAMMING PROGRAMS
C
C          QUADPR MINIMIZES OR MAXIMIZES  COST*X + X*QUAD*X
C                 SUBJECT TO     A*X + KT*'SLACK' = RHS
C                                                 X .GE. 0.
C                 (KT(I)=-1,0,+1 IF I-TH CONSTRAINT IS .GE.,.EQ.,.LE.)
C                 THE OBJECTIVE FUNCTION SHOULD BE CONVEX (CONCAVE)
C                 FOR MINIMIZATION (MAXIMIZATION) PROBLEMS.
C                 THIS MEANS THE SYMMETRIC MATRIX QUAD+QUAD(TRANSPOSE)
C                 SHOULD BE NONNEGATIVE (NONPOSITIVE) DEFINITE
C                 FOR MINIMIZATION (MAXIMIZATION) PROBLEMS.
C
C    CALLING SEQUENCE ...
C    CALL QUADPR (A,KT,RHS,COST,QUAD,INPUT,TOL,TITLE,PFILE,
C   *   OBJ,X,RC,DUAL,SLK,IOUT,WS)
C
C    IN WHAT FOLLOWS, MO = NO. OF CONSTRAINTS, NO = NO. OF VARIABLES,
C    DIMENSION SIZES GIVEN ARE THE MINIMUM REQUIRED.
C
C A      --- MO X NO - CONSTRAINT MATRIX
C KT     --- MO-VECTOR OF CONSTRAINT TYPES,  -1,0,+1 MEAN .GE.,.EQ.,.LE.
C            RESPECTIVELY
C RHS    --- MO-VECTOR OF RIGHT-HAND-SIDE VALUES
C COST   --- NO-VECTOR OF LINEAR COSTS
C QUAD   --- NO X NO MATRIX OF QUADRATIC COSTS
C INPUT  --- FIXED CONSTANTS VECTOR OF LENGTH 21 CONTAINING ...
C ML       1 ROW DIMENSION OF A IN CALLING PROGRAM.  MINIMUM IS MO.
C NL       2 ROW DIMENSION OF QUAD IN CALLING PROGRAM.  MINIMUM IS NO.
C MO       3 NUMBER OF CONSTRAINTS.
C NO       4 NUMBER OF VARIABLES .
C MINMAX   5 =0 IF OBJECTIVE IS TO BE MINIMIZED,
C            =1 IF OBJECTIVE IS TO BE MAXIMIZED.
C LENWS    6 DIMENSION OF WS IN CALLING PROGRAM.  MINIMUM IS
C            2*(MO+NO)**2 + 12*(MO+NO) + 16 IF ANY EQUALITY CONSTRAINTS
C            ARE PRESENT OR  2*(MO+NO)**2 +  8*(MO+NO) + 6
C            IF ALL CONSTRAINTS ARE INEQUALITIES.
C MAXIT    7 PIVOT LIMIT.
C KOBJ     8 COMPUTE OBJECTIVE AT SOLUTION OPTION.  =0 NO, =1 YES.
C JIT      9 OUTPUT PROBLEM PARAMETERS OPTION.   =0 NO, =1 YES.
C JDATA   10 OUTPUT PROBLEM DATA OPTION.  =0 NO,
C            =1 OUTPUT WITH A AND QUAD MATRICES IN DENSE FORM,
C            =2 OUTPUT WITH A AND QUAD MATRIX IN SPARSE FORM.
C JPIVOT  11 OUTPUT PIVOT INFORMATION.  =0 NO, =1 YES.
C JSOL    12 OUTPUT SOLUTION REPORT OPTION.  =0 NO,
C            =1 OUTPUT BRIEF REPORT,  =2 OUTPUT FULL REPORT.
C JOUT    13 OPTION TO PRINT OR FILE OUTPUT.
C            =0 PRINT ALL OUTPUT,  =1 PRINT PROBLEM PARAMETERS AND FINAL
C            OUTPUT AND FILE OTHER OUTPUT, =2 FILE ALL OUTPUT.
C JWIDTH  14 MAXIMUM WIDTH OF OUTPUT LINES.  A MINIMUM OF 72 AND A
C            MAXIMUM OF 132 WILL BE USED.
```

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```
C      L1 = LEN(PFILE)
       L1 = 30

       L2 = 0
       L3 = 0
       DO 30 I = 1, L1
          IF (PFILE(I:I) .EQ. ' ') GO TO 30
          L2 = L2 + 1
          PFILES(L2:L2) = PFILE(I:I)
    30 CONTINUE
       IF (L2 .GT. 0) GO TO 40
C      BLANK FILE NAME, DISCARD OUTPUT TO BE FILED.
       JDATA = 0
       JPIVO = 0
       IF (JOUT .EQ. 2) GO TO 90
       JIT = 0
       JSOL = 0
       GO TO 50
C      OPEN PRINT FILE.
    40 CONTINUE
C       OPEN (LUFILE,FILE=PFILES,STATUS='UNKNOWN',ERR=60)
       OPEN (LUFILE,FILE=PFILES)
       IO3 = LUFILE
       IF (JOUT .EQ. 1) GO TO 50
       IO2 = LUFILE
       GO TO 90
    50 CONTINUE
       IO2 = LUPRNT
       GO TO 90
C      CANNOT OPEN FILE. MAKE ONE UP.
    60 CONTINUE
       IF (L3 .EQ. 1) GO TO 76
       L3 = 1
       WRITE (IO1,70) NCALL,PFILES(1:L2)
    70 FORMAT ( //// 5X,'QUADPR  CALL',I4
      1        // 1X,'*** UNABLE TO OPEN THE FILE ', A)
       WRITE (PFILES,72) NCALL
C      FORM FILE NAME.
    72 FORMAT ('QDPR',I4.4,'.LIS',52X)
       WRITE (IO1,74) PFILES(1:12)
    74 FORMAT ( / 5X,'OUTPUT WILL BE FILED ON ',A12)
       GO TO 40
C      CANNOT OPEN THIS FILE EITHER.
    76 CONTINUE
       WRITE (IO1,78) LUFILE
    78 FORMAT ( / 5X,'CANNOT OPEN THIS FILE EITHER.  CHECK YOUR FILES ',
      1    'FOR THE ABOVE NAME' / 5X,'AND MAKE SURE LOGICAL UNIT',I4,
      2    ' IS CLOSED.' / )
       IERR = 5
       GO TO 200
    80 CONTINUE
       IO2 = LUPRNT
```

```
       DOUBLE PRECISION  PIVOT
       COMMON /QPRCBD/ PIVOT
C
       CHARACTER*64  TITLES, PFILES
       COMMON /QPRCBC/ TITLES, PFILES
C
C      DATA NCALL  / 0 /

       NCALL = 0
C
C      OUTPUT UNITS FOR LINE PRINTER (TERMINAL) AND OUTPUT FILE
       DATA  LUPRNT, LUFILE  / 6, 92 /
C
C
C      INITIALIZATIONS
C
       IO1 = LUPRNT
       IERR = 0
       ITCNT = 0
       TZERO = TOL(1)
       TPIV = TOL(2)
       NCALL = NCALL + 1
       DO 10 I = 1, 14
          INPUTS(I) = INPUT(I)
    10 CONTINUE
       TITLES =
      *'

C      L1 = LEN(TITLE)
       L1 = 30

       TITLES(1:L1) = TITLE(1:L1)
C
C      INTERNAL TABLEAU IS (MO+NO)*(MO+NO+1) IF ALL INEQUALITIES AND
C      (MO+NO+1)*(MO+NO+2) IF ANY EQUALITIES SINCE 1 MORE ROW IS ADDED.
       IF (MO .LE. 0) GO TO 22
       DO 20 I = 1, MO
          IF (KT(I) .EQ. 0) GO TO 24
    20 CONTINUE
    22 CONTINUE
       MORE = 0
       GO TO 26
    24 CONTINUE
       MORE = 1
    26 CONTINUE
       P = MO + NO + MORE
       P1 = P + 1
       PSQ = P**2
C
C      SET OUTPUT UNITS AND OPEN PRINT FILE IF REQUIRED.
       IF (JOUT .NE. 1 .AND. JOUT .NE. 2) GO TO 80
       PFILES =
      *'
```

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```
C
      IMPLICIT REAL (A-H,O-Z)
      DIMENSION KT(1)
C
      INTEGER  ROW,COL,INDX,P,P1,PSQ
      COMMON /QPRCBI/ INPUTS(14),IOUTS(2),ROW,COL,INDX,MORE,P,P1,PSQ,
     1   NCALL,LENREQ,IO1,IO2,IO3
      EQUIVALENCE (INPUTS(1),ML), (INPUTS(2),NL), (INPUTS(3),MO),
     1   (INPUTS(4),NO), (INPUTS(5),MINMAX), (INPUTS(6),LENWS),
     2   (INPUTS(7),MAXIT), (INPUTS(8),KOBJ), (INPUTS(9),JIT),
     3   (INPUTS(10),JDATA), (INPUTS(11),JPIVOT), (INPUTS(12),JSOL),
     4   (INPUTS(13),JOUT), (INPUTS(14),JWIDTH),
     5   (IOUTS(1),IERR), (IOUTS(2),ITCNT)
C
      COMMON /QPRCBR/ TOLS(2)
      EQUIVALENCE (TOLS(1),TZERO), (TOLS(2),TPIV)
C
      INTEGER ZERONE(4),ZERO12(3)
      LOGICAL ERROR(10)
      DATA ZERONE  / 5,8,9,11 /
      DATA ZERO12  / 10,12,13 /
C
C
      ITITLE = 0
C
C     DEFAULT VALUES
      IF (MAXIT .LE. 0) MAXIT = 1000
      IF (TZERO .LE. 0.0) TZERO = 1.0E-7
      IF (TPIV .LE. 0.0) TPIV = 1.0E-6
      IF (JWIDTH .LT. 72) JWIDTH = 72
      IF (JWIDTH .GT. 132) JWIDTH = 132
C
      ITITLE = 0
C
C     CHECK KT
      DO 10 I = 1, MO
         IF (IABS(KT(I)) .GT. 1) GO TO 20
   10 CONTINUE
      GO TO 30
   20 CONTINUE
      WRITE (IO1,22) NCALL
   22 FORMAT ( /// 5X,'QUADPR  CALL',I4)
      WRITE (IO1,24) (KT(I),I=1,MO)
   24 FORMAT ( / 1X,'*** ERROR, ILLEGAL VALUES IN KT.  KT CONTAINS'
     1  / (5I12) )
      IERR = 5
      ITITLE = 1
C
C     CHECK INPUT
   30 CONTINUE
      ERROR(1) = (MO .LT. 0 .OR. MO .GT. ML)
      ERROR(2) = (NO .LT. 1 .OR. NO .GT. NL)
      IO3 = LUPRNT
   90 CONTINUE
C
C     PARTITION WORKSPACE ARRAY.
      L1 = 1 + 2*(PSQ+P)
      L2 = L1 + 2*P1
      L3 = L2 + 2*P1
      L4 = L3 + P1
      LENREQ = L4 + P1 - 1
C
C     CHECK INPUT DATA PARAMETERS FOR CONSISTENCY
      CALL QDRVER (KT)
C
      IF (IERR .EQ. 5) GO TO 200
C     QUIT IF BAD VALUES (IERR = 5)
C
C     OUTPUT PROBLEM PARAMETERS AND PROBLEM DATA IF REQUESTED.
C      IF (JIT .NE. 0) CALL QRPRT1
C      IF (JDATA .NE. 0) CALL QRPRT2 (A,ML,KT,RHS,COST,QUAD,NL)
C
C     OUTPUT HEADER FOR INTERMEDIATE OUTPUT, IF ANY EXPECTED
C      IF (JPIVOT .NE. 0) CALL QRPRT3
C
C     CONSTRUCT INITIAL TABLEAU FOR QUADRATIC PROGRAMMING.
      CALL QDPREP (A,ML,KT,RHS,COST,QUAD,NL,WS,P)
C
C     PERFORM PRINCIPAL PIVOTING TO FINAL TABLEAU.
      CALL QDCOMP (WS,WS(L1),WS(L2),WS(L3),WS(L4))
C
C     GET SOLUTION AND OBJECTIVE VALUE IF REQUESTED.
      CALL QDSOLN (KT,COST,QUAD,NL,WS,P,WS(L4),X,RC,DUAL,SLK,
     1   WS(L1),OBJ)
C
C     OUTPUT SOLUTION REPORT IF REQUESTED.
C      IF (JSOL .NE. 0) CALL QRPRT6 (X,RC,DUAL,SLK,OBJ)
C
C     SET EXIT VALUES, IOUT.
  200 CONTINUE
      IOUT(1) = IERR
      IOUT(2) = ITCNT
C
C     CLOSE PRINT FILE IF REQUIRED.
      IF (JOUT .GT. 0) CLOSE (LUFILE,STATUS='KEEP')
C
      RETURN
C
      END
*****************************************************************

      SUBROUTINE QDRVER (KT)
C
C     CHECK INPUT DATA FOR QUADPR
```

```
C     B     .....................................
C           :     A'            :     0       : -RHS' :
C           :     [4]           :    [5]      : [6]   :
C           .....................................
C
C     WHERE A',RHS',COST',QUAD' ARE OBTAINED FROM A,RHS,COST,QUAD BY
C     CONVERTING THE PROBLEM TO MINIMIZATION WITH ALL .GE. CONSTRAINTS.
C
      IMPLICIT REAL (A-H,O-Z)

      DOUBLE PRECISION B
      DIMENSION  A(LDA,1),KT(1),RHS(1),COST(1),QUAD(LDQ,1),B(LDB,1)
C
      INTEGER  ROW,COL,INDX,MORE,P,P1,PSQ
      COMMON /QPRCOM/ INPUTS(14),IOUTS(2),ROW,COL,INDX,MORE,P,P1,PSQ,
     1  NCALL,LENREQ,IO1,IO2,IO3
      EQUIVALENCE (INPUTS(1),ML), (INPUTS(2),NL), (INPUTS(3),MO),
     1    (INPUTS(4),NO), (INPUTS(5),MINMAX), (INPUTS(6),LENWS),
     2    (INPUTS(7),MAXIT), (INPUTS(8),KOB), (INPUTS(9),JIT),
     3    (INPUTS(10),JDATA), (INPUTS(11),JPIVOT), (INPUTS(12),JSOL),
     4    (INPUTS(13),JOUT), (INPUTS(14),JWIDTH),
     5    (IOUTS(1),IERR), (IOUTS(2),ITCNT)
C
C
C     FILL LOWER TRIANGLE OF [1] AND [3].
      N1 = P0 - 1
      IF (MINMAX .EQ. 1) GO TO 40
C     MIN. PROBLEM
      B(1,1) = 2.0*QUAD(1,1)
      B(1,P1) = COST(1)
      IF (NO .EQ. 1) GO TO 110
      DO 10 K = 2, NO
         B(K,K) = 2.0*QUAD(K,K)
         B(K,P1) = COST(K)
   10 CONTINUE
      DO 30 L = 1, N1
         L1 = L + 1
         DO 20 K = L1, NO
            B(K,L) = QUAD(K,L) + QUAD(L,K)
   20    CONTINUE
   30 CONTINUE
      GO TO 90
C     MAX. PROBLEM
   40 CONTINUE
      B(1,1) = - 2.0*QUAD(1,1)
      B(1,P1) = - COST(1)
      IF (NO .EQ. 1) GO TO 110
      DO 50 K = 2, NO
         B(K,K) = - 2.0*QUAD(K,K)
         B(K,P1) = - COST(K)
   50 CONTINUE
      DO 70 L = 1, N1
```

```
      ERROR(3) = (LENWS .LT. LENREQ)
      DO 33 I = 1, 4
         J = ZERONE(I)
         ERROR(I+3) = (INPUTS(J) .NE. 0 .AND. INPUTS(J) .NE. 1)
   33 CONTINUE
      DO 34 I = 1, 3
         J = ZERO12(I)
         ERROR(I+7) = (INPUTS(J) .LT. 0 .OR. INPUTS(J) .GT. 2)
   34 CONTINUE
      DO 35 I = 1, 10
         IF (ERROR(I)) GO TO 38
   35 CONTINUE
      GO TO 50
C
   38 CONTINUE
      IERR = 5
      IF (ITITLE .EQ. 0) WRITE (IO1,22) NCALL
      WRITE (IO1,40) (INPUTS(I),I=1,14)
   40 FORMAT ( / 1X,'*** ERROR, INCONSISTENT DATA IN INPUT.'
     1  '  INPUT CONTAINS' / 5I12 / 5I12 / 4I12 /
     2  / 5X,'THE FOLLOWING ERRORS OCCURRED.' / )
      IF (ERROR(1)) WRITE (IO1,41)
   41 FORMAT (5X,'INPUT(3) NEGATIVE OR EXCEEDS INPUT(1)')
      IF (ERROR(2)) WRITE (IO1,42)
   42 FORMAT (5X,'INPUT(4) NON-POISTIVE OR EXCEEDS INPUT(2)')
      IF (ERROR(3)) WRITE (IO1,43) LENREQ
   43 FORMAT (5X,'INPUT(6) TOO SMALL.  FOR THIS PROBLEM,',
     1   ' MUST BE AT LEAST',I8)
      DO 45 I = 1, 4
         J = ZERONE(I)
         IF (ERROR(I+3)) WRITE (IO1,46) J
   45 CONTINUE
   46 FORMAT (5X,'INPUT(',I2,') NOT 0 OR 1')
      DO 47 I = 1, 3
         J = ZERO12(I)
         IF (ERROR(I+7)) WRITE (IO1,48) J
   47 CONTINUE
   48 FORMAT (5X,'INPUT(',I2,') NOT 0, 1, OR 2')
C
   50 CONTINUE
      RETURN
      END
*****************************************************************

      SUBROUTINE QDPREP (A,LDA,KT,RHS,COST,QUAD,LDQ,B,LDB)

C     CONSTRUCT THE INITIAL TABLEAU FOR QUADRATIC PROGRAMMING.
C     IT HAS THE FORM
C           .....................................
C           :          (T)    :    (T)     :    :
C           : QUAD'+QUAD      :   -A       : COST':
C           :    [1]          :   [2]      : [3]  :
```

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```
            B(K,L) = A(I,L)
  180     CONTINUE
          B(K,P1) = - RHS(I)
          GO TO 210
C         .LE. CONSTRAINT
  190     CONTINUE
          DO 200 L = 1, NO
             B(K,L) = - A(I,L)
  200     CONTINUE
          B(K,P1) = RHS(I)
  210 CONTINUE
C
C     FILL [2].
      DO 230 L = 1, NO
         DO 220 K = N1, P
            B(L,K) = - B(K,L)
  220    CONTINUE
  230 CONTINUE
C
C     FINISHED
  240 CONTINUE
      RETURN
      END
*****************************************************************************

      SUBROUTINE QDCOMP (B,TEMP,U,JZ,JW)
C
C     COMPUTE THE FINAL TABLEAU FOR QUADRATIC PROGRAMMING GIVEN
C     THE INITIAL TABLEAU USING THE METHOD OF PRINCIPAL PIVOTING.
C
      IMPLICIT REAL (A-H,O-Z)

      DOUBLE PRECISION  B,TEMP,U
      INTEGER  JZ,JW
      DIMENSION  B(1),TEMP(1),U(1),JZ(1),JW(1)
C
      INTEGER  ROW,COL,INDX,P,P1,PSQ
      COMMON /QPRCBI/ INPUTS(14),IOUTS(2),ROW,COL,INDX,MORE,P,P1,PSQ,
     1   NCALL,LENREQ,IO1,IO2,IO3
      EQUIVALENCE (INPUTS(1),ML), (INPUTS(2),NL), (INPUTS(3),MO),
     1   (INPUTS(4),NO), (INPUTS(5),MINMAX), (INPUTS(6),LENWS),
     2   (INPUTS(7),MAXIT), (INPUTS(8),KOBJ), (INPUTS(9),JIT),
     3   (INPUTS(10),JDATA), (INPUTS(11),JPIVOT), (INPUTS(12),JSOL),
     4   (INPUTS(13),JOUT), (INPUTS(14),JWIDTH),
     5   (IOUTS(1),IERR), (IOUTS(2),ITCNT)
C
      COMMON /QPRCBR/ TOLS(2)
      EQUIVALENCE (TOLS(1),TZERO), (TOLS(2),TPIV)
C
      DOUBLE PRECISION  PIVOT
      COMMON /QPRCBD/ PIVOT
C
          L1 = L + 1
          DO 60 K = L1, NO
             B(K,L) = - QUAD(K,L) - QUAD(L,K)
   60     CONTINUE
   70 CONTINUE
C
C     FILL UPPER TRAINGLE OF [1].
   80 CONTINUE
      DO 100 L = 2, NO
         L1 = L - 1
         DO 90 K = 1, L1
            B(K,L) = B(L,K)
   90    CONTINUE
  100 CONTINUE
C
C     CHECK FOR CASE OF NO CONSTRAINTS.
  110 CONTINUE
      IF (MO .EQ. 0) GO TO 240
C
C     FILL [5].
      N1 = NO + 1
      DO 130 L = N1, P
         DO 120 K = N1, P
            B(K,L) = 0.0
  120    CONTINUE
  130 CONTINUE
C
C     IF THERE ARE R .EQ. CONSTRAINTS, EXPRESS AS R+1 .GE. CONSTRAINTS,
C     THE LATTER BEING MINUS THE SUM OF THE OTHERS.
      IF (MORE .EQ. 0) GO TO 150
      DO 140 L = 1, NO
         B(P,L) = 0.0
  140 CONTINUE
      B(P,P1) = 0.0
C
C     FILL [4] AND [6].
  150 CONTINUE
      DO 210 I = 1, MO
         K = NO + I
         IF (KT(I) .LT. 0) GO TO 170
         IF (KT(I) .GT. 0) GO TO 190
C        .EQ. CONSTRAINT
         DO 160 L = 1, NO
            B(K,L) = A(I,L)
            B(P,L) = B(P,L) - B(K,L)
  160    CONTINUE
         B(K,P1) = - RHS(I)
         B(P,P1) = B(P,P1) - B(K,P1)
         GO TO 210
C        .GE. CONSTRAINT
  170    CONTINUE
         DO 180 L = 1, NO
```

```
         IF (B(IJ) .LT. (-TZERO)) GO TO 90
C********IF ALL COL. ELEMENTS ARE NONNEGATIVE, THEN THE DRIVING VARIABLE
C********IS UNBLOCKED AND THERE IS NO SOLUTION.
         IF (B(KJ) .GE. (-TPIV)) GO TO 90
         Z = -B(IJ) / B(KJ)
         IF (Z .GE. TMMP) GO TO 90
         TMMP = Z
         ROW = J
   90 CONTINUE
      IF (ROW. EQ. 0) GO TO 420
      COL = II
      GO TO 150
C*****COMPUTE Z = -Q(R)/B(R,R), THE INCREASE IN THE DRIVING VARIABLE.
  100 IJ = PSQ + I
      KJ = P*(I-1) + I
      Z = -B(IJ) / B(KJ)
      COL = I
  110 BS = 0.
      ROW = 0
C*****FIND THE NEW BLOCKING VARIABLE, BASED ON WHICH BASIC VARIABLE IS
C*****MOST AFFECTED BY THE CHANGE IN THE DRIVING VARIABLE.
      IJ = (COL-1)*P
      KJ = PSQ
      DO 140 J = 1, P
         IJ = IJ + 1
         KJ = KJ + 1
         BST = B(IJ)*Z + B(KJ)
         IF (B(KJ) .LT. (-TZERO) .OR. BST .GE. (-TPIV)) GO TO 140
         IF (DABS(B(KJ)) .LT. TZERO .AND. B(IJ) .LT. (-TZERO)) GO TO 120

         IF (B(KJ)) 130, 140, 130
  120    ROW = J
         GO TO 150
  130    BST = -BST / B(KJ)
         IF (BST .LE. BS) GO TO 140
         BS = BST
         ROW = J
  140 CONTINUE
      IF (ROW .EQ. 0) GO TO 210
C*****NONPRINCIPAL PIVOT ON B(S,R).
C*****AT THIS POINT THE BLOCKING VARIABLE IS B(NS,I).
  150 III = -JW(ROW)
      NFLAG = 1
      GO TO 500
  160 CONTINUE
      IF (ITCNT .GE. MAXIT) GO TO 440
      ITCNT = ITCNT + 1
C*****ATTEMPT TO PROGRESSIVELY RELAX THE CONVERGENCE PARAMETER

C     TPIV = TPIV + TOLS(2)/50.
C*****INDICATE THE NUMBER OF ITERATIONS
      WRITE(*,101)'OPTIMIZATION ITERATION      ',ITCNT
```

```
      DOUBLE PRECISION  Z,BS,BST
      CHARACTER*48  MSG(4)
C
      DATA MSG / 'ALGORITHM ERROR, INDEX VALUE NON-DECREASING.    ',
     2           'NO SOLUTION, INVALID QUADRATIC COSTS MATRIX.    ',
     3           'NO SOLUTION, INFEASIBLE OR UNBOUNDED PROBLEM.   ',
     4           'ERROR, ITERATION LIMIT REACHED.                 '/
C
C
C*****INITIALIZATIONS
      ITCNT = 0
      JFLAG = 0
      INDX = P1
C*****BASIC VARIABLES GET NEGATIVE VALUES.
C*****NONBASIC VARIABLES(JZ) GET POSITIVE VALUES.
      DO 30 I = 1, P
         JW(I) = -I
         JZ(I) = I
   30 CONTINUE
   40 ITEMP = 0
C*****CHECK FOR NONDECREASING INDEX (ALLOW UP TO 5 EQUAL INDEXES FOR
C*****TOLERANCE PURPOSES).
      IJ = PSQ
      DO 50 I = 1, P
         IJ = IJ + 1
         IF (B(IJ) .LT. (-TZERO)) ITEMP = ITEMP + 1
   50 CONTINUE
      IF (ITEMP .NE. INDX) ICT = 0
      IF (ITEMP .EQ. INDX) ICT = ICT + 1
      IF (ITEMP .GT. INDX .OR. ICT .EQ. 5) GO TO 400
C*****IF THE INDEX IS ZERO YOU ARE DONE.
      IF (ITEMP .EQ. 0) GO TO 300
      INDX = ITEMP
      IJ = PSQ
      DO 60 I = 1, P
         IJ = IJ + 1
         IF (B(IJ) .LT. (-TZERO)) GO TO 70
   60 CONTINUE
   70 IJ = P*(I-1) + I
C*****CHECK FOR NEGATIVE DIAGONAL ELEMENT (NOT ALLOWED IF POS. SEMIDEF.)
      IF (B(IJ) .LT. (-TPIV)) GO TO 410
      IF (B(IJ) .GT. TPIV) GO TO 100
C*****IF POTENTIAL PIVOT ELEMENT IS NEAR ZERO, USE CODE BELOW
C*****TO DETERMINE THE BLOCKING VARIABLE.
      II = I
   80 ROW = 0
      TMMP = 1000000.
      IJ = PSQ
      KJ = P*(II-1)
      DO 90 J = 1, P
         IJ = IJ + 1
         KJ = KJ + 1
```

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```
C*****EXCHANGE COLUMNS
  260 LLL = 0
      DO 280 J = 1, P
         K = IABS(JZ(J))
         IF (K .EQ. J) GO TO 280
         IJ = P*(K-1)
         KJ = P*(J-1)
         DO 270 I = 1, P
            IJ = IJ + 1
            KJ = KJ + 1
            Z = B(IJ)
            B(IJ) = B(KJ)
            B(KJ) = Z
  270    CONTINUE
         II = JZ(J)
         JZ(J) = JZ(K)
         JZ(K) = II
         LLL = LLL + 1
  280 CONTINUE
      IF (LLL .GE. 2) GO TO 260
  290 ROW = LL
      ITCNT = ITCNT + 1
C*****ATTEMPT TO PROGRESSIVELY RELAX THE CONVERGENCE PARAMETER

C     TPIV = TPIV + TOLS(2)/50.
C*****INDICATE THE NUMBER OF ITERATIONS
      WRITE(*,101)'OPTIMIZATION ITERATION       ',ITCNT

C     IF (JPIVOT .EQ. 1) CALL QRPRT5
      IF (INDX .GT. 1) GO TO 40
C
C*****NORMAL TERMINATION
  300 IERR = 1
      GO TO 600
C
C*****ERROR TERMINATION
  400 K = 1
      IERR = 6
      GO TO 460
  410 K = 2
      IERR = 4
      GO TO 460
  420 K = 3
      IERR = 2
      GO TO 460
  440 K = 4
      IERR = 3
  460 WRITE (101,470) MSG(K),ITCNT
      IF (JOUT .NE. 0) WRITE (103,470) MSG(K),ITCNT
  470 FORMAT( / 1X,A48,I6,' PIVOTS PERFORMED.' / )
      GO TO 600
C
  101 FORMAT('+',A50,I5)

      JFLAG = 0
C*****PUT TOLERANCE ON B(I,P1) AFTER A NONPRINCIPAL PIVOT.
      IJ = PSQ + I
      IF (B(IJ) .LT. (-TZERO)) GO TO 170
      GO TO 40
C*****THE NEW DRIVING VARIABLE IS THE COMPLEMENT OF THE OLD BLOCKING
C*****VARIABLE
  170 DO 180 JJ = 1, P
         IF (JZ(JJ) .EQ. III) GO TO 190
  180 CONTINUE
C*****NO COMPLEMENT VARIABLE (NOT ALLOWED IF POS. SEMIDEF.)
      GO TO 410
  190 COL = JJ
C*****THE DISTINGUISHED VARIABLE IS STILL THE I-TH ROW.
      IJ = P*(COL-1) + I
      IF (B(IJ) .GT. TPIV) GO TO 200
      II = COL
      GO TO 80
  200 KJ = PSQ + I
      Z = -B(KJ) / B(IJ)
      GO TO 110
C*****PRINCIPAL PIVOT ON B(I,I).
  210 LL = ROW
      ROW = I
      NFLAG = 2
      GO TO 500
  220 CONTINUE
      IF (JFLAG .EQ. 1) GO TO 290
      JFLAG = 1
C*****MUST REARRANGE THE ROWS AND COLUMNS FOR COMPLEMENTARITY
C*****EXCHANGE ROWS
  230 LLL = 0
      DO 250 I = 1, P
      K = IABS(JW(I))
      IF (K .EQ. I) GO TO 250
      IJ = K
      KJ = I
      DO 240 J = 1, P1
         Z = B(IJ)
         B(IJ) = B(KJ)
         B(KJ) = Z
         IJ = IJ + P
         KJ = KJ + P
  240 CONTINUE
      II = JW(I)
      JW(I) = JW(K)
      JW(K) = II
      LLL = LLL + 1
  250 CONTINUE
      IF (LLL .GE. 2) GO TO 230
```

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```
**********************************************************************

      SUBROUTINE QDSOLN (KT,COST,QUAD,LDQ,B,LDB,JW,X,RC,DUAL,SLK,
     1   TEMP,OBJ)
C
C     RETURN SOLUTION TO QUADRATIC PROGRAMMING PROBLEM FROM FINAL
C     TABLEAU AND COMPUTE OBJECTIVE VALUE IF REQUESTED.
C     CONVERTING THE PROBLEM TO MINIMIZATION WITH ALL .GE. CONSTRAINTS.
C
      IMPLICIT REAL (A-H,O-Z)

      DOUBLE PRECISION  B,TEMP
      DIMENSION  KT(1),COST(1),QUAD(LDQ,1),B(LDB,1),JW(1),X(1),RC(1),
     1   DUAL(1),SLK(1),TEMP(1)
C
      INTEGER  ROW,COL,INDX,MORE,P,P1,PSQ
      COMMON /QPRCBI/ INPUTS(14),IOUTS(2),ROW,COL,INDX,MORE,P,P1,PSQ,
     1   NCALL,LENREQ,IO1,IO2,IO3
      EQUIVALENCE (INPUTS(1),ML), (INPUTS(2),NL), (INPUTS(3),MO),
     1   (INPUTS(4),NO), (INPUTS(5),MINMAX), (INPUTS(6),LENWS),
     2   (INPUTS(7),MAXIT), (INPUTS(8),KOBJ), (INPUTS(9),JIT),
     3   (INPUTS(10),JDATA), (INPUTS(11),JPIVOT), (INPUTS(12),JSOL),
     4   (INPUTS(13),JOUT), (INPUTS(14),JWIDTH),
     5   (IOUTS(1),IERR), (IOUTS(2),ITCNT)
C
      COMMON /QPRCBR/ TOLS(2)
      EQUIVALENCE (TOLS(1),TZERO), (TOLS(2),TPIV)
C
      DOUBLE PRECISION DART, BB

C
C
C     GET X, RC, DUAL, SLK
  100 CONTINUE
      KART = MO + 1
      DO 110 J = 1, NO
         X(J) = 0.0
         RC(J) = 0.0
  110 CONTINUE
      DO 120 I = 1, MO
         DUAL(I) = 0.0
         SLK(I) = 0.0
  120 CONTINUE
      DART = 0.0D0
      DO 170 I = 1, P
         BB = B(I,P1)
         IF (DABS(BB) .LT. TZERO) BB = 0.0D0
         J = JW(I)
         IF (J .LT. 0) GO TO 150
         IF (J .GT. NO) GO TO 130
         X(J) = BB
         GO TO 170
  130    CONTINUE
C*****PIVOT CODE.
C*****QUADPP USES A NORMAL JORDAN PIVOT.
C*****HOWEVER, WE CAN SAVE MEMORY BY USING THE ELEMENTARY MATRIX.
C*****STORE PIVOT ELEMENT
  500 CONTINUE
      KC = P*(COL-1)
      KJ = KC + ROW
      PIVOT = B(KJ)
      Z = 1.0D0 / PIVOT
C*****STORE ELEMENTARY-VECTOR AND U-VECTOR.
      IJ = ROW
      ISAVE = I
      DO 510 I = 1, P1
         U(I) = B(IJ)
         IJ = IJ + P
  510 CONTINUE
      IJ = KC
      DO 520 I = 1, P
      IJ = IJ + 1
         TEMP(I) = -B(IJ) * Z
  520 CONTINUE
      TEMP(ROW) = -Z - 1.0D0
C*****COMPUTE ALL COLUMNS EXCEPT PIVOT COLUMN.
      IJ = 0
      DO 550 J = 1, P1
         IF (J .NE. COL) GO TO 530
         IJ = IJ + P
         GO TO 550
  530    DO 540 I = 1, P
            IJ = IJ + 1
            B(IJ) = B(IJ) + U(J)*TEMP(I)
  540    CONTINUE
  550 CONTINUE
C*****COMPUTE PIVOT COLUMN.
      IJ = KC
      DO 560 I = 1, P
         IJ = IJ + 1
         B(IJ) = -TEMP(I)
  560 CONTINUE
C*****COMPUTE NEW PIVOT ELEMENT.
      B(KJ) = Z
C*****KEEP TRACK OF BASIC AND NONBASIC VARIABLES
      K = JW(ROW)
      JW(ROW) = JZ(COL)
      JZ(COL) = K
C     IF (JPIVOT .EQ. 1) CALL QRPRT4
      I = ISAVE
      GO TO (160, 220), NFLAG
C
C*****FINISHED
  600 RETURN
      END
```

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```
      SUBROUTINE QSET(NUM,MAXWS,ITURN)
*****************************************************************************
      INCLUDE 'COMMON.F'
      REAL QC(NDID,ND),QRHS(NDID),QTOL(2),QRC(ND),D2X(ND),XOLD(ND),
     &                 QDUAL(NDID),QSLK(NDID),QWS(ISIZEQ)

      INTEGER QKT(NDID),INPUT(14),QIOUT(2),NUM,MAXWS
      CHARACTER*30 PFILE

      DO 10 I = 1,ID
      DO 10 J = 1,NUM
         QC(I+NUM,J)=C(J,I)
10    CONTINUE

      DO 20 I = 1,NUM
      DO 20 J = 1,NUM
         IF(I.EQ.J) THEN
            QC(I,J) = -1.0
         ELSE
            QC(I,J) = 0.0
         END IF
20    CONTINUE

      DO 30 I = 1,NUM+ID
         IF(I.LE.NUM) THEN
           QRHS(I) = -BDU(I)
         ELSE
            QRHS(I) = D(I-NUM)
         END IF
         QKT(I) = -1
30    CONTINUE

      INPUT(1) = ND+ID
      INPUT(2) = ND
      INPUT(3) = NUM+ID
      INPUT(4) = NUM
      INPUT(5) = 0
      INPUT(6) = MAXWS
      INPUT(7) = 0
      INPUT(8) = 0
      INPUT(9) = 0
      INPUT(10) = 0
      INPUT(11) = 0
      INPUT(12) = 0
      INPUT(13) = 0
      INPUT(14) = 0

     QTOL(1) = 0.0
C E-6
C     QTOL(2) = 0.000001
C E-4
      QTOL(2) = 0.0001
```

```
         K = J - NO
         IF (K .EQ. KART) GO TO 140
         DUAL(K) = BB
         GO TO 170
  140    CONTINUE
         DART = BB
         GO TO 170
  150    CONTINUE
         J = -J
         IF (J .GT. NO) GO TO 160
         RC(J) = BB
         GO TO 170
  160    CONTINUE
         K = J - NO
         IF (K .EQ. KART) GO TO 170
         SLK(K) = BB
  170 CONTINUE
C
C     ADJUST DUALS IF ANY EQUALITIES
      IF (MORE .EQ. 0) GO TO 200
      DO 190 I = 1, MO
         IF (KT(I) .NE. 0) GO TO 190
         IF (MINMAX .EQ. 1) GO TO 180
         DUAL(I) = DUAL(I) - DART
         GO TO 190
  180    CONTINUE
         DUAL(I) = DART - DUAL(I)
  190 CONTINUE
C
C     COMPUTE OBJECTIVE VALUE ONLY IF REQUESTED.
  200 CONTINUE
      IF (KOBJ .EQ. 0) GO TO 250
      OBJ = 0.
      DO 220 I = 1, NO
         TEMP(I) = 0.0D0
         DO 210 J = 1, NO
            TEMP(I) = TEMP(I) + X(J)*QUAD(I,J)
  210    CONTINUE
  220 CONTINUE
      DO 230 J = 1, NO
         OBJ = OBJ + TEMP(J)*X(J)
  230 CONTINUE
      DO 240 J = 1, NO
         OBJ = OBJ + COST(J)*X(J)
  240 CONTINUE
C
C     FINISHED
  250 CONTINUE
      RETURN
      END
C*****************************************************************************
*****************************************************************************
```

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```
        B(I) = TURN*ABS(X(I)-OLDWT(I))
60    CONTINUE
      RETURN
      END
C *********************************************************************
```

```
      PFILE = 'TEMP.Q'
      DO 40 I = 1,NUM
         B(I) = 0.0
         D2X(I) = 0.0
         XOLD(I) = 0.0
40    CONTINUE

      DXLAST = 1.0
      C0 = 0.1E-3
      C1 = 0.90
      C2 = 1.0
      TURN = TURN * 0.001
      GO TO 501
500   WRITE(*,150)ITURN
150   FORMAT(1X,T60,I4)

      CALL QUAD1 (QC,QKT,QRHS,B,A,INPUT,QTOL,TITLE,
     &            PFILE,OBJ,X,QRC,QDUAL,QSLK,QIOUT,QWS)


501   DXTOTAL = 0.0

      DO 45 I = 1,NUM
         IF (ITURN .EQ. 0) THEN
            X(I) = OLDWT(I)
         ELSE
            X(I) = XOLD(I) + C1*(X(I)-XOLD(I))
         END IF
45    CONTINUE

      DO 50 I = 1,NUM
         A(I,I) = A(I,I) - D2X(I)
         DX = X(I) - OLDWT(I)
         DXTOTAL = DXTOTAL + ABS(DX)
         D2X(I) = 0.5*TURN*(1.0/SQRT(DX*DX+C0)-DX*DX/(DX*DX+C0)**1.5)
         A(I,I) = A(I,I) + D2X(I)
         B(I) =  TURN*DX/SQRT(DX*DX + C0) - 2.0*X(I)*D2X(I)
         XOLD(I) = X(I)
50    CONTINUE

      WRITE(*,'(1X,A12,F9.3)')'TURN OVER = ',DXTOTAL*50.

      IF (ABS(DXTOTAL-DXLAST).GT. 0.01 .OR. ITURN .LT. 1) THEN
         ITURN = ITURN + 1
         DXLAST = DXTOTAL
         GO TO 500
      END IF

      TURN = 0.0
      DO 60 I = 1,NUM
         A(I,I) = A(I,I) - D2X(I)
```

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```
*****************************************************************
C *** PARAMETERS ARE USED TO DIMENSION THE COMMON ARRAYS         *
C *** IN EACH SUBROUTINE.                                       *
C ***                                                          *

C ***   ND  =  TOTAL NUMBER OF STOCK WEIGHTS BEING COMPUTED.   *
C ***   ID  =  THE MAXIMUM NUMBER OF CONSTRAINT EQUATIONS.     *
C ***   N2D =  THE DIMENSION ON WORKING AREAS ( 2 * ND )       *
C ***   KEQ =  NUMBER OF CONSTRAINTS WHICH WILL BE EQUALITIES  *

C ***   NRT =  NUMBER OF RETURNS                               *
C ***   NST =  USED FOR STATISTICS                             *

C ***   ISIZEQ = 2 * ( ND*2 + ID )**2 + 8*(ND*2+ID) +6         *
C ***   NDID = ND + ID                                         *

C *********        FOR CASH RUNS (AT LEAST 1 EQ CONST. )
C ***   ISIZEQ = 2 * ( ND*2 + ID )**2 + 12*(ND*2+ID) +16       *
C ***   NDID = ND + ID                                         *

C *****************************************************************
C       LAST UPDATED: November 19, 1988
      IMPLICIT REAL (A-H,O-Z)
      IMPLICIT INTEGER (I-N)
      PARAMETER (KEQ = 0)
C 280
C     PARAMETER (ND =  280, ID = 6 , N2D = 560)
C     PARAMETER (NDID = 286, ISIZEQ = 645246)
C 250
C     PARAMETER (ND =  250, ID = 6 , N2D = 500)
C     PARAMETER (NDID = 256, ISIZEQ = 516126)
C 100
C     PARAMETER (ND =  100, ID = 6 , N2D = 200)
C     PARAMETER (NDID = 106, ISIZEQ = 86526)

      PARAMETER (NRT = 48, NST = 3)
      PARAMETER (LENGTH = 40)
      CHARACTER*(LENGTH) FILEOUT,TITLE,NAME(ND),PORTRETS,GARB,ANSWER,
     &          OLD,LIANAME,LIABIN,STOCKIN,BONDIN,IDC(ND),SIC(99)

      COMMON /ARRY/ A(ND,ND),C(ND,ID)
      COMMON /VECT/ B(ND),D(ID),BDL(ND),BDU(ND),X(ND),OLDWT(ND)
      COMMON /RETS/ RET(NRT,ND),ANIM(NRT),PRET(NRT),ISIC(ND),AVE(ND)
      COMMON /TRAC/ COV(NST,NST),STAT(NRT,NST),COREL(NRT,NST)
      COMMON /TRA2/ PRICE(ND),VOL(ND),CUM(ND),VAR(3),LIANAME,TITLE
      COMMON /RTNIN/FILEOUT,LIABIN,STOCKIN,BONDIN,IDC,NAME,SIC
      COMMON /DAT/  NMSAVE,NM,NSIMS,NSTOCKS,NBONDS,NSTAT,NRETS,IDUMMY,
     &              IHOLD
      COMMON /MAX/  STOCKMIN,YIMAX,SMAX,SCALE,BRET,XFACTOR,XBUPPER,
     &       XBLOWER,BULLET,TARGET,TURN,BULL1,TARG1,TURN1,PORTVAL
C  END OF COMMON.F
```

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APPENDIX II

LIABILITY RETURN PROGRAM

To create a return series for a liability stream from yields.

(Appendix II pp. 1-2)

```
READ(11,1500)GARB
READ(11,1500)GARB
READ(11,*)IYLD1
READ(11,*)IYLD2
DO 333 I=IYLD1,IYLD2
    READ(11,*)YTM(I)
CONTINUE
CLOSE (11)

OPEN (10,FILE=RETOUT,STATUS='NEW')

IF(OLDOUT.EQ.1)THEN
    OPEN (8,FILE=OLDFILE)
    READ(8,1500)TITLE
    READ(8,1500)GARB
    READ(8,1500)GARB
    READ(8,1500)GARB
    READ(8,1500)GARB
    READ(8,1500)GARB
    READ(8,*)IRET1
    READ(8,*)IRET2
    IF(IRET2.GE.IYLD2)THEN
        WRITE(*,*)'CAN T UPDATE RETURN FILE CHECK YIELDS FILE'
        STOP
    ENDIF
    WRITE(10,1500)TITLE
    WRITE(10,1500)GARB
    WRITE(10,1500)GARB
    WRITE(10,1500)GARB
    WRITE(10,1500)GARB
    WRITE(10,1500)GARB
    WRITE(10,*)IRET1
    WRITE(10,*)IYLD2

    DO 500 I=IRET1,IRET2
        READ  (8,*)RS,PV1,PV2,MM,DUR
        WRITE (10,2001)RS,PV1,PV2,MM,DUR
    CONTINUE
    CLOSE(8)
ELSE
    IRET1=IYLD1+1
    WRITE(*,*)' ENTER TITLE FOR RETURN FILE'
    READ(*,1500)TITLE
    WRITE(10,1500)TITLE
    WRITE(10,1500)GARB
    WRITE(10,1500)GARB
    WRITE(10,1500)GARB
    WRITE(10,1500)GARB
    WRITE(10,1500)GARB
    WRITE(10,*)IRET1
    WRITE(10,*)IYLD2
ENDIF
```

```
$LARGE
$DEBUG
C       LIABILITY RETURN PROGRAM
C       AUTHOR JOE DADA III
C       LAST UPDATE 3-21-88
C       COPYWRITE 1988 NATIONAL INVESTMENT SERVICES OF AMERICA INC.


        PROGRAM SPANRATE


$INCLUDE: 'RATE.FOR'

C                               CALL SUBS TO GET INPUT DATA
C       CALL INTRO

C                               ITYPE=1,ABO;=2,PBO

C                       THIS SECTION TO BE REMOVED AND BY SUB INTRO
C       LIAIN='TEMP.LIA'
C       YIELDS='NYTM.PRN'
C       OLDFILE='TEMP.LIR'
C       RETOUT='TEMP2.LIR'
C       OLDOUT=1

        WRITE(*,*)' DOES OLD OUTPUT FILE EXIST ? Y/N'
        READ(*,1500)GARB
        IF(GARB.EQ.'Y'.OR.GARB.EQ.'y')THEN
            OLDOUT=1
            WRITE(*,*)' ENTER NAME OF OLD RETURN FILE'
            READ(*,1500)OLDFILE
        ELSE
            OLDOUT=0
        ENDIF
        WRITE(*,*)' ENTER LIABILITY STREAM FILENAME'
        READ(*,1500)LIAIN
        WRITE(*,*)' ENTER NEW OUTPUT FILENAME'
        READ(*,1500)RETOUT
        WRITE(*,*)'RETOUT',RETOUT
        WRITE(*,*)' ENTER YIELD TO MATURITY FILENAME'
        READ(*,1500)YIELDS




        OPEN (11,FILE=YIELDS)
        READ(11,1500)GARB
        READ(11,1500)GARB
        READ(11,1500)GARB
        READ(11,1500)GARB
```

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```
      OPEN (9,FILE=LIAIN)
      DO 448 I=1,1000
         READ(9,*,END = 449)XLIA(I)
448   CONTINUE
      CLOSE(9)

449   NYEARS=I-1
      NMONTHS=NYEARS*12
      IF(NYEARS.GT.90)THEN
         WRITE(*,*)' ERROR LIA STREAM HAS TOO MANY YRS 90 IS MAX'
         STOP
      ENDIF

C                CALCULATE MONTHLY YIELDS AND SLIDE
C                OLD YIELD BACK TO BEG OF MONTH

      DO 222 I=1,NYEARS
         XLIA(I)=XLIA(I)/12
222   CONTINUE

      IF(OLDOUT.EQ.1)THEN
         ISTART=IRET2-1
      ELSE
         ISTART=IYLD1
      ENDIF
      ICHECK=ISTART+1
      DO 100 I=ISTART,IYLD2
C          WRITE(*,*)'I',I,'YLD',YTM(1)
C     +     ,XLIA(1)
         FR1=FR
         FR=(1+YTM(I))**(0.083333)-1

C              SKIP TO END OF LOOP FIRST TIME THROUGH
         IF(FR1.EQ.0)GO TO 100
C              PROD IS DENOMINATOR TO CONV FUTURE TO PV
         PV1=0.0
         PV2=0.0
         PROD1=1.0
         PROD2=1.0
         DUR=0
         DO 300 J=1,NYEARS
            DO 300 L=1,12
               PROD1=PROD1*(1+FR1)
               PV1=PV1+XLIA(J)/PROD1
               DUR=DUR+(J+L/12)*XLIA(J)/PROD1
               IF(J.EQ.1.AND.L.EQ.1)GOTO 400
               PROD2=PROD2*(1+FR)
400            PV2=PV2+XLIA(J)/PROD2
300      CONTINUE
         RR=PV2/PV1-1.0
         DUR=DUR/PV1

C              IF OLDFILE EXIST CHECK LAST RETURN IN IT
C              VERSUS NEW CALC TO CHECK PARAMETERS

      IF(OLDOUT.EQ.1.AND.I.EQ.ICHECK)THEN
        IF(RS.GT.RR+.00001.OR.RS.LT.RR-.00001)THEN
           WRITE(*,*)' PARAMETERS NOT SAME AS OLD OUTPUT
           WRITE(*,*)' OLD RET',RS,' NEW RET',RR,' I',I
           STOP
        ELSE
           GOTO 100
        ENDIF
      ENDIF
110   WRITE (10,2001)RR,PV1,PV2,I,DUR
      WRITE(*,343)'RETURN DATA',I,PV1,PV2,RR,DUR
100   CONTINUE
      CLOSE(10)

343   FORMAT(A10,I4,4X,F17.0,4X,F13.0,4X,F10.6,3X,F5.2)
1500  FORMAT(A40)
2001  FORMAT(F13.10,2F15.0,I4,3X,F5.2)

      STOP
      END
```

APPENDIX III

CORRELATION PORTFOLIO PROGRAM

To create an optimal index correlation portfolio with securities.

(Appendix III pp. 1-30)

```
      END IF

C**********  SET UP CONSTANTS *********************

      NUM = NSTOCKS+NBONDS
      IF(NUM.GT.ND)THEN
          WRITE(*,*)' WARNING NUM >',ND,' TOO BIG FOR PROGRAM'
          STOP
      ENDIF

      ICOL = ID
      KE = KEE
      KKK = KK
      IA = ND
      ICC = NN
      IH = N2D

      IFIRST = NM-NSTAT
      ILAST = NM+NSIMS-1

      BULL1 = BULLET
      TARG1 = TARGET
      TURN1 = TURN

      BULLET = BULLET*ABS(BULLET)/1000.
      IF (TURN1.EQ.100.)THEN
         TURN = 0.0
      ELSE
         TURN = TURN1/50.
      END IF
C     ************************   CALL COVIN TO READ IN RETURNS     ******
      CALL COVIN (NUM,IREAD,IFIRST,ILAST)

C     ************************   CALL HOLDING TO FOR CURRENT WEIGHTS ****
      CALL HOLDING (NUM)

C     ************************   CALL MATRIX TO CALCULATE  INPUT ARRAYS *
      WRITE(*,101)'CALLING MATRIX  ........      '
      CALL MATRIX (NUM,IREAD)

C     ***************************************************************
      WRITE(*,101)'CALLING BOUNDS  .......      '
      CALL BOUNDS (NUM,ICOL,MMM)

C     ***************************************************************

C     **********  **********   CALL TO OPTIMIZER      *****************

      WRITE(*,101)'CALLING OPTIMIZER  ......    '
      IF (ICOUNT.EQV. .TRUE.) THEN
         WRITE(*,102)'WORKING ON RUN NUMBER     ',ISKIP
      END IF
```

```
C UPDATED December 6, 1988
C ****************************************************************
      PROGRAM SPAN
C ****************************************************************

      INCLUDE 'COMSUC.F'

      LOGICAL ICOUNT
C *************          DATA INPUT SECTION     ************************

5     CONTINUE

C     DEFAULT READ IN OF 24 MONTHS PRIOR  = NSTAT, NRESTS FOR B( ) ****

      NSTAT = 24
      NRETS = 24
      BULLET = 0.0
      TARGET = 1.
      TURN = 100.
      ITYPE = 1
      ICHANGE = 0
      XBLOWER = .0D0
      XBUPPER = 3.0D0
      SMAX = XBUPPER

C     **********************       CALL FLASH TO INTRODUCE   S P A N   ****
C     CALL FLASH

C     *************  IF 'COUNTS' EXISTS THIS IS A MULTIPLE RUN      ****
      INQUIRE (FILE = 'COUNTS', EXIST = ICOUNT)

      IF (ICOUNT .EQV. .FALSE.)   THEN
C     **********************       CALL INTRO TO INPUT PARAMETERS      ****
         CALL INTRO
C     **********************       CALL MODIFY TO CHANGE PARAMETERS    ****
         CALL MODIFY

C     **********************  ICOUNT  IS TRUE  --> CALL MULTRUN   *********
      ELSE
         CALL MULTRUN(ISKIP)
      END IF

C     **********************       CALL SAVDAT TO SAVE   PAST.DAT      ****
      CALL SAVDAT
C     ***************************************************************

      NM = NMSAVE
      NM = (INT(NM/100)-80)*12+(NM-INT(NM/100)*100)
      IREAD = NSTAT+NSIMS

      IF(NSTOCKS.GT.0)THEN
        XBUPPER = SMAX
```

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```
          DO 20 J = 1,18
          READ(13,'(A1)',END = 99)GARB
20        CONTINUE
10      CONTINUE

30      CONTINUE
        READ(13,101,END = 99)TITLE
        READ(13,101, END = 99) FILEOUT
        READ(13,101, END = 99) LIABIN
        READ(13,101, END = 99) STOCKIN
        READ(13,101, END = 99) BONDIN
        READ(13,*, END = 99) NMSAVE
        READ(13,*, END = 99) NSIMS
        READ(13,*, END = 99) NSTOCKS
        READ(13,*, END = 99) NBONDS
        READ(13,*, END = 99) IDUMMY
        READ(13,*, END = 99) STOCKMIN
        READ(13,*, END = 99) YIMAX
        READ(13,*, END = 99) SMAX
        READ(13,*, END = 99) NSTAT
        READ(13,*, END = 99) NRETS
        READ(13,*, END = 99) BULLET
        READ(13,*, END = 99) TARGET
        READ(13,*, END = 99) TURN

101     FORMAT (A20)

        ISKIP = ISKIP+1

        CLOSE(13)
        RETURN

C *****     STOP  DONE WITH MULTI RUN      **********
99      CLOSE(13)
        WRITE(*,*)'DONE WITH MULTIPLE RUN ********************'
        STOP
        END
*****************     END OF SUBROUTINE  MULTRUN     ******************
*******************************************************************************
        SUBROUTINE HOLDING (NUM)
*******************************************************************************
        INCLUDE 'COMSUC.F'

        DIMENSION VAL(ND)
        CHARACTER*9 SYMBL,IDCSYM(ND)
        CHARACTER*12 HOLD
        LOGICAL HOLDEX

C **** IHOLD IS READ FROM FIRST SCREEN RESPONSE: OLD OR HOLDINGS RUN **
        IF (IHOLD .EQ. 0) GO TO 999

11      WRITE(*,*)'INPUT PORTFOLIO #, AND NAME OF HOLDINGS FILE'
```

```
        MAXWS = 2*(2*NUM+ID)*(2*NUM+ID)+8*(2*NUM+ID)+6
        ITURN = 0
        CALL QSET ( NUM, MAXWS,ITURN )
C   *********    IF TURNOVER IS CONSIDERED, CALL TURNOV

        IF(TURN.GT.0) THEN
           ITURN = 1
           CALL QSET (NUM, MAXWS, ITURN)
        END IF


C   **********************   CALL TO PORTFOLIO OUTPUT    ***************
        WRITE(*,*)
        WRITE(*,101)'CALLING PORT  .....      '
        CALL PORT (NUM)
        IF (IDUMMY .EQ. 1) GO TO 100

C   **********************    CALL TO STATISTICAL TRACKING      *********
        WRITE(*,101)'CALLING TRACKER  .......      '
        CALL TRACKER (NUM,IREAD)

C   **********************    CALL TO TURNOVER ROUTINE          *********
        WRITE(*,101)'CALLING BAL  ...........      '
        CALL BAL (NUM)
C   *******************************************************************************

100     WRITE(*,101)'SPANNING SIMULATION COMPLETE'
        IF (ICOUNT.EQV. .TRUE.) THEN
           WRITE(*,102)'DONE WITH RUN NUMBER     ',ISKIP
           GO TO 5
        END IF

101     FORMAT('+',A50)
102     FORMAT('+',A50,I7)


        END
C                       END OF MAIN PROGRAM SPAN1
C   *******************************************************************************
*******************************************************************************
        SUBROUTINE MULTRUN (ISKIP)
*******************************************************************************

        INCLUDE 'COMSUC.F'
        CHARACTER*30 XTITL,XFLOUT,XLIBIN,XSTKIN,XBNDIN

        OPEN (13,FILE ='MULTIN',STATUS = 'OLD')

        IF (ISKIP.EQ.0) GO TO 30

        DO 10 I = 1, ISKIP
```

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```
      IDCTEST = 0
      NCOUNT = 0
      DO 20 I = 2,NIDC
         ITEST = 0
         DO 30 J = 1,NUM
            IF(IDC(J)(1:4) .EQ. IDCSYM(I)) THEN
               ITEST = 1
               NCOUNT = NCOUNT+1
               OLDWT(J) = VAL(I) / PORTVAL
            END IF
30       CONTINUE
      IF (ITEST .EQ. 0) THEN
         IDCTEST = 1
         WRITE(*,*)IDCSYM(I),': SYMBOL NOT INCLUDED IN RETURN FILE'
      END IF
20    CONTINUE

      IF (IDCTEST.EQ.1) THEN
        WRITE(*,*)NIDC-NCOUNT-1,'SYMBOLS NOT FOUND..PROGRAM STOPPING'
        STOP
      END IF
      RETURN


999   OPEN(21,FILE = 'OLD',STATUS = 'OLD')
      DO 90 I = 1,NUM
         READ(21,*)OLDWT(I)
         IF (TURN.EQ. 0.0)OLDWT(I) = 0.0
         OLDWT(I) = OLDWT(I)/100.
90    CONTINUE
      CLOSE(21)
      RETURN

      END
C ************************      END OF SUBROUTINE  HOLDING      **************
C  UPDATE 8/9/88
C  ***********  THIS SUBROUTINE READS IN STOCK, BOND & LIA DATA ********

      SUBROUTINE COVIN (NUM,IREAD,IFIRST,ILAST)

C  ***************************************************************************

C              IFIRST IS FIRST MONTH OF DATA NEEDED FOR MATRIX
C              ILAST IS LAST MONTH OF SIMULATION
C
      INCLUDE 'COMSUC.F'

C ******************   READ IN LIABILITY RETURNS ************************

      OPEN (9,FILE = LIABIN, STATUS = 'OLD')

      READ (9,111) LIANAME
```

```
      READ(*,*)IPORT,HOLD
      INQUIRE (FILE = HOLD,EXIST = HOLDEX)
      IF (HOLDEX .EQV. .FALSE.) THEN
          WRITE(*,*)'FILE NOT FOUND ',HOLD
          GO TO 11
      END IF

      OPEN (25,FILE = HOLD,STATUS = 'OLD')

      XPORT = REAL(IPORT)
      I = 0
22    READ(25,*, END = 44)SYMBL,VALUE
      IF (SYMBL .EQ. 'IDCSYMBL') THEN
         IF (VALUE .EQ. XPORT) THEN
            READ(25,*,END = 44)GARB
            READ(25,*, END = 44)SYMBL,VALUE
33             IF (SYMBL .EQ. 'IDCSYMBL") GO TO 44
                  I = I + 1
                  IDCSYM(I) = SYMBL
                  VAL(I) = VALUE
                  GO TO 33
         END IF
      READ(25,*,END = 44) GARB
      END IF
      GO TO 22

44    CONTINUE
      NIDC = I
      IF (NIDC .EQ. 0)THEN
         WRITE(*,*)'PORTFOLIO NUMBER NOT FOUND ', IPORT
         GO TO 11
      END IF

      ICASH = 0
      PORTVAL = 0.0
      DO 10 I=1,NIDC
         PORTVAL = PORTVAL + VAL(I)
         IF (IDCSYM(I) .EQ. 'CASH')THEN
            ICASH = 1
            TEMP = VAL(I)
            VAL(I) = VAL(1)
            VAL(1) = TEMP
            GARB = IDCSYM(I)
            IDCSYM(I) = IDCSYM(1)
            IDCSYM(1) = GARB
         END IF
10    CONTINUE
      IF (ICASH .EQ. 0) THEN
         WRITE(*,*)'NO CASH INCLUDED....PROGRAM STOPPING'
         STOP
      END IF
```

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```
          ILEN = 1
          IDC(I) = '          '
  791     IF (GARB(ILEN:ILEN).EQ.' ') THEN
              ILEN = ILEN + 1
              IF ((ILEN+3).GT.LENGTH) GOTO 793
              GOTO 791
          ENDIF

          IDC(I)(1:4) = GARB(ILEN:ILEN+3)
          ILEN = ILEN + 4

  792     IF (GARB(ILEN:ILEN).EQ.' ') THEN
              ILEN = ILEN + 1
              IF ((ILEN+3).GT.LENGTH) GOTO 793
              GOTO 792
          ENDIF
          IDC(I)(6:9) = GARB(ILEN:ILEN+3)

  793     CONTINUE

              READ (4,*) ISIC(I)
              IF(ISIC(I).GT.99) ISIC(I) = INT (ISIC(I)/100)
              READ (4,111) (GARB,L = 4,5)
              READ (4,*) ISTART
              READ (4,*) ISTOP

C *****       TEST FOR ENOUGH RETURNS TO SATISFY NRETS  ****************

              ICHECK = NM-NRETS-ISTART
              IF(ICHECK.LT.0) NRETS = NM - ISTART
              IF(NRETS.LT.NSTAT) ICHECK = IFIRST-ISTART

              DO 800 J = 1,ICHECK
                  READ (4,111) GARB
  800         CONTINUE

              DO 801 J = 1,NRETS-NSTAT
                  READ(4,*)GARB
  801         CONTINUE

              JJ = NRETS-NSTAT

              DO 810 K = 1,IREAD
               READ (4,*) RET(K,I)

C ****  ADJUST OCTOBER 1987 ********************
        IF(K+NM-NSTAT-1.EQ.94.)THEN
          IF(K.LE.NSTAT)RET(K,I)=RET(K,I)/2.97
        END IF
                  J = JJ+K
  810         CONTINUE
```

```
          WRITE(*,*)LIANAME
          DO 200 I = 1,5
              READ (9,111) GARB
  200     CONTINUE

          READ (9,*) ISTART
          READ (9,*) ISTOP

          DO 300 I = 1,IFIRST-ISTART
              READ (9,111) GARB
  300     CONTINUE

          DO 400 I = 1,IREAD
              READ (9,*) ANIM(I)
  400     CONTINUE

          CLOSE(9)

C                                          READ IN STOCK DATA
          IF (NSTOCKS.GT.0) THEN
              OPEN (4,FILE = STOCKIN, STATUS = 'OLD')

              DO 600 I = 1,IDUMMY
                  READ (4,111) (GARB,L = 1,6)
                  READ (4,*) ISTART
                  READ (4,*) ISTOP
                 DO 610 K = 1,ISTOP-ISTART+1
                  READ (4,*) XGARB
  610             CONTINUE
  600         CONTINUE
  111     FORMAT (A30)

              DO 700 I = 1,NSTOCKS
  783             READ (4,111,END = 785) NAME(I)

C  **** CUT OFF LEADING BLANKS OF NAME(I)
              ILEN = 1
              GARB = '                                        '
  790         IF (NAME(I)(ILEN:ILEN) .EQ. ' ')THEN
                 ILEN = ILEN+1
                 GO TO 790
              ELSE
                 GARB(1:LENGTH) = NAME(I)(ILEN:LENGTH)
              END IF
              NAME(I) = GARB

                  WRITE (*,112) I,NAME(I)
  112             FORMAT('+','STOCK # ',I5,' IS ',A30)
                  READ (4,111) GARB

C  ****  CUT OUT BLANKS FROM GARB TO GET AN IDC AND TICKER
              READ (4,111) GARB
```

```
      CLOSE(7)
      RETURN

C ***    IF END OF FILE WAS HIT ON STOCKS - RESET NUM AND CONTINUE ***
785   NSTOCKS = I-1
      NUM = NSTOCKS+NBONDS
       GOTO 1400

      END
C                                          END OF SUBROUTINE COVIN
C
C*************************************************************************

C ********************* MATRIX CALCULATION SUBROUTINE ********************
      SUBROUTINE MATRIX (NUM,IREAD)
C*************************************************************************
      INCLUDE 'COMSUC.F'

C                     IREAD = NSTAT+NSIMS
C                     NUM = NSTOCKS+NBONDS
      UANIM = 0.0
      DO 198 I = 1,NUM
         AVE(I) = 0.0
         DO 199 J = 1,NSTAT
            AVE(I) = AVE(I)+RET(J,I)/DBLE(NSTAT)
199      CONTINUE
198   CONTINUE

      UANIM = 0.
      DO 129 I = 1,NSTAT
        UANIM = UANIM + ANIM(I)*TARGET/DBLE(NSTAT)
129   CONTINUE

      XXX = DBLE(NSTAT-1)
      DO 130 I = 1,NUM
         B(I) = 0.0
         DO 131 J = 3,NSTAT

      TEMPI = (1+RET(J,I))*(1+RET(J-1,I))*(1+RET(J-2,I))-1.0
      TEMPJ = (1+ANIM(J))*(1+ANIM(J-1))*(1+ANIM(J-2))-1.0
      B(I) = B(I)+(TEMPI-AVE(I)*3.)*(TEMPJ*TARGET-UANIM*3.) / XXX
131      CONTINUE
130      CONTINUE

C NOW CALCULATES COVAR AND SIGMA PURE
CCCCC REMOVE COMMENTS DOWN TO CCCCCC LINE TO USE SIGMA DIFF
C      BRET = 0.0
C      DO 233 I = 1,NUM
C      OLDWT(I) = OLDWT(I)/100.
C      BRET = BRET + OLDWT(I)*OLDWT(I)
C         DO 244 J = 1,NSTAT
C            RET(J,I) = RET(J,I)-ANIM(J)*TARGET
```

```
         DO 1200 J = 1,ISTOP-ILAST
            READ (4,111) GARB
00       CONTINUE

00    CONTINUE
ENDIF
00  CONTINUE
    CLOSE(4)
                        READ IN BOND DATA

    IF (NBONDS.GT.0) THEN
    OPEN (7,FILE = BONDIN, STATUS = 'OLD')

    DO 900 I = NSTOCKS+1,NSTOCKS+NBONDS
       READ (7,111) NAME(I)
       WRITE (*,113) I,NAME(I)
       READ (7,111) (GARB,L = 1,5)
       READ (7,*) ISTART
       READ (7,*) ISTOP
13     FORMAT('+','BOND  # ',I5,' IS ',A30)
 *****  TEST ICHECK FOR ENOUGH RETURNS FOR BRET  ********************

          ICHECK = NM-NRETS-ISTART
          IF(ICHECK.LT.0) THEN
       WRITE(*,*)'BOND ',I,' DOES NOT HAVE ENOUGH RETURNS FOR NRETS'
             STOP
          END IF
          IF(NRETS.LT.NSTAT) ICHECK = IFIRST-ISTART

       DO 1000 J = 1,ICHECK
          READ (7,111) GARB
1000   CONTINUE

       DO 1001 J = 1,NRETS-NSTAT
         READ(7,*)GARB
1001   CONTINUE

       JJ = NRETS-NSTAT

        DO 1010 K =1,IREAD
       READ (7,*) RET(K,I)
          J = JJ + K
1010    CONTINUE

       DO 1300 J = 1,ISTOP-ILAST
          READ (7,111) GARB
1300   CONTINUE

 900 CONTINUE

     ENDIF
```

```
      CONTINUE
   CONTINUE

      TURN IS USED TO ADJUST IMPORTANCE OF DELTA X   *********

   DO 213 I = 1,NUM
      AVE(I) = 0.0
      DO 214 J = 1,NSTAT
         AVE(I) = AVE(I)+RET(J,I)/DBLE(NSTAT)
4  CONTINUE

3  CONTINUE
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

*******       CALCULATE COVARIANCE MATRIX  **********
   XXX = DBLE(NSTAT-1)
   DO 215 I = 1,NUM
      DO 215 J = I,NUM
         A(I,J) = 0
         DO 215 K = 3,NSTAT

   TEMPI = (1+RET(K,I))*(1+RET(K-1,I))*(1+RET(K-2,I))-1.0
   TEMPJ = (1+RET(K,J))*(1+RET(K-1,J))*(1+RET(K-2,J))-1.0

   A(I,J) = A(I,J)+(TEMPI-AVE(I)*3.)*(TEMPJ-AVE(J)*3.) / XXX

   A(J,I) = A(I,J)

   IF(A(I,J).GT.50)WRITE(*,*)'COV TOO BIG',A(I,J),I,J
215  CONTINUE

TEST TO SEE IF RETURNS HAVE BEEN RESET FOR OCTOBER 1987 ***
   IF(94.GE.NM-NSTAT.AND.94.LE.NM-1)ITRUE = 1
   DO 387 I = 1,NUM
*******     FOR ADDING K*IDENTITY TO  [A]   ******************
      A(I,I) = A(I,I)+TURN
   IF(ITRUE.EQ.1)RET(94-NM+NSTAT+1,I)=RET(94-NM+NSTAT+1,I)*2.97
      B(I) = B(I)*BULLET
387  CONTINUE

   RETURN

   END                                  END OF SUBROUTINE MATRIX
C  ***************************************************************
C  ***************************  SUBROUTINE BOUNDS ****************
C    SUBROUTINE BOUNDS (NUM,ICOL,MMM)
C  ***************************************************************

      INCLUDE 'COMSUC.F'
```

```
   SCAL = 1.25
   SIC49 = 0.0
   SIC60 = 0.0
   SIC63 = 0.0
   SIC67 = 0.0


   DO 80 I = 1,NUM
      BDL(I) = XBLOWER/100.0
      BDU(I) = XBUPPER/100.0
      IF(OLDWT(I).GT.BDU(I))THEN
        IF(OLDWT(I).GT.SCAL*BDU(I)) THEN
          BDU(I) = SCAL*BDU(I)
        ELSE
          BDU(I) = OLDWT(I)
        END IF
      END IF
      IF (I.GT.NSTOCKS) BDU(I) = 1.

      IF(ISIC(I).EQ.48) SIC49 = SIC49+OLDWT(I)
      IF(ISIC(I).EQ.49) SIC49 = SIC49+OLDWT(I)
      IF(ISIC(I).EQ.60) SIC60 = SIC60+OLDWT(I)
      IF(ISIC(I).EQ.63) SIC63 = SIC63+OLDWT(I)
      IF(ISIC(I).EQ.67) SIC67 = SIC67+OLDWT(I)
80    CONTINUE

      D(1) =  STOCKMIN/100.0
      D(2) =  100.0/100.0
      D(3) = -100.01/100.0
      D(4) = -YIMAX/100.0
      D(5) = -YIMAX/100.0
      D(6) = -YIMAX/100.0

   SIC60S = SIC60+SIC63+SIC67
   IF(SIC49*100.GT.YIMAX.AND.SIC49*100.LT.SCAL*YIMAX)D(4) = -SIC49
   IF(SIC60S*100.GT.YIMAX.AND.SIC60S*100.LT.SCAL*YIMAX)D(5)=-SIC60S
   IF(SIC67*100.GT.YIMAX.AND.SIC67*100.LT.SCAL*YIMAX)D(6) = -SIC67

   IF( SIC49*100.GT.SCAL*YIMAX)  D(4) = D(4)*SCAL
   IF( SIC60S*100.GT.SCAL*YIMAX) D(5) = D(5)*SCAL
   IF( SIC67*100.GT.SCAL*YIMAX)  D(6) = D(6)*SCAL

      DO 51 J = 1,ICOL
         DO 52 I = 1,NUM
            C(I,J) = 0.0
            IF (J.EQ.1.AND.I.LE.NSTOCKS)  C(I,J) = 1.0
            IF (J.EQ.2) C(I,J) = 1.0
            IF (J.EQ.3) C(I,J) = -1.0
            IF (J.EQ.4.AND.ISIC(I).EQ.49)    C(I,J) =  -1.0
            IF (J.EQ.4.AND.ISIC(I).EQ.48)    C(I,J) =  -1.0
            IF (J.EQ.5.AND.ISIC(I).EQ.60)    C(I,J) =  -1.0
            IF (J.EQ.5.AND.ISIC(I).EQ.63)    C(I,J) =  -1.0
```

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```
      RETURN
      END IF

C     ********************  PRINT SPANNING SIMULATION RESULTS ***

      OPEN(10,FILE=FILEOUT,STATUS='UNKNOWN')
      REWIND(10)

      WRITE(10,*)' NATIONAL INVESTMENT SERVICES SPANNING TECHNOLOGY'
      WRITE(10,*)'                SIMULATION RESULTS'
      WRITE(10,*)
      WRITE(10,*)'                ',TITLE
      WRITE(10,*)
      WRITE(10,*)' LIABILITY STREAM USED  ',LIANAME
      WRITE(10,*)
      WRITE(10,*)'       START    END    SPANNING'
      WRITE(10,*)'NUMBER WEIGHT  WEIGHT SENSITIVITY SIC #  IDC    ',
     &           'SECURITY NAME'
      WRITE(10,*)

C  ******    CALCULATE THE PORTFOLIO RETURNS   **********************
C  ******    FIRST CALCULATE RETURNS FOR NSTAT PERIOD ***************
      DO 800 I = 1,NSTAT
          PRET(I) = 0.0
          DO 900 J = 1,NUM
              PRET(I) = PRET(I) + RET(I,J)*X(J)
 900      CONTINUE
 800  CONTINUE
C  ******    NOW CALCULATE RETURNS AND WEIGHTS IN SIMULATION PERIOD *
      DO 801 I=1,NSIMS
          PRET(I+NSTAT)=0.0
          DO 901 J=1,NUM
              PRET(I+NSTAT) = PRET(I+NSTAT)+CUM(J)*RET(I+NSTAT,J)
 901      CONTINUE
          DO 1001 K = 1,NUM
              CUM(K) = CUM(K)*(1.+RET(I+NSTAT,K))/(1.+PRET(I+NSTAT))
1001      CONTINUE
 801  CONTINUE

C ***  WRITE OUT THE NEW WEIGHTS TO A FILE CALLED 'OLD'********
      OPEN(15,FILE = 'OLD', STATUS = 'OLD')
      REWIND(15)
      DO 140 I = 1,NUM
      WRITE(15,940) CUM(I)*100
140   CONTINUE
940   FORMAT(1X,F15.8)
      CLOSE(15)

C  ******    CALCULATE PARTIALS AND WRITE OUTPUT  ******************
      XVAR = 0.0
      XCOVAR = 0.0
      XRET = 0.0
```

```
                IF (J.EQ.5.AND.ISIC(I).EQ.67)    C(I,J) =  -1.0
                IF (J.EQ.6.AND.ISIC(I).EQ.67)    C(I,J) =  -1.0

 52           CONTINUE
 51         CONTINUE

C     CLOSE (6)

      MMM = 2*NUM+ICOL

      RETURN

      END
C                          END OF SUBROUTINE BOUNDS
C ***************************************************************************

C     ***********************************************************************
      SUBROUTINE PORT (NUM)
C     ***********************************************************************

      INCLUDE 'COMSUC.F'

C     ********************  BEGIN OUTPUT PROCEDURES **************
      UANIM = 0.0
      DO 129 I = 1,NRETS
      UANIM = UANIM + ANIM(I)/DBLE(NRETS)
129   CONTINUE
      UANIM = UANIM*TARGET

      XTOT=0.
      IDUMMY = 0

      DO 130 I=1,NUM
        XTOT=XTOT+X(I)
        CUM(I) = X(I)
        IF(X(I).LT. -0.001) THEN
      WRITE(*,*)' '
      WRITE(*,*)'**************   SPANNING RUN ABORTED   **************'
      WRITE(*,*)'  WEIGHT NUMBER ',I,' = %',X(I)*100.
      WRITE(*,*)'*****************************************************'
      IDUMMY = 1
      RETURN
      END IF

130   CONTINUE

      IF (ABS(XTOT-1.0) .GT. 0.005) THEN
      WRITE(*,*)' '
      WRITE(*,*)'**************   SPANNING RUN ABORTED   **************'
      WRITE(*,*)'  TOTAL WEIGHT IN PORTFOLIO = %',XTOT*100.
      WRITE(*,*)'*****************************************************'
      IDUMMY = 1
```

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```
      ICOUNT=0

      DO 131 I=1,NUM
          IF(BULLET.NE.0.0)B(I) = B(I)/BULLET
          C(I,1)= 0.0
          DO 132 J=1,NUM
              C(I,1)=C(I,1)+X(J)*2.0*A(I,J)
              XVAR=XVAR+X(I)*X(J)*A(I,J)
 132      CONTINUE
          XRETI = AVE(I) + UANIM
          XRET = XRET + X(I)*XRETI
          XCOVAR = XCOVAR + X(I)*B(I)
 131  CONTINUE

      DO 150 I = 1,NUM
         C(I,1) = B(I)*XVAR**(-0.5)-0.5*XCOVAR*C(I,1)*XVAR**(-1.5)

         ICOUNT=ICOUNT+1
         WRITE(10,16)ICOUNT,X(I)*100,CUM(I)*100,C(I,1)*100,
     &                ISIC(I),IDC(I),NAME(I)
 150  CONTINUE
 16   FORMAT(1X,I4,1X,2F8.3,F10.6,I4,2X,A9,2X,A30)
      WRITE(10,*)


      STD=(XVAR*12)**(.5)*100
      XRET = XRET*12.0*100.0
      XCOVAR = XCOVAR*1200

      WRITE(10,649) STD, XRET, XCOVAR
 649  FORMAT(1X,' MINIMUM STD DEV =',F10.4,'  EXPECTED RETURN =',F10.4,
     & ' COVARIANCE = ',F10.4)
      WRITE(10,*)

C     IF(ITYPE.EQ.1.AND.XTOT.LT..995)WRITE(10,*)' ERROR ****** ',
C    .' SUM OF X S = %',XTOT*100.
C     IF(ITYPE.EQ.1.AND.XTOT.GT.1.005)WRITE(10,*)' ERROR ****** ',
C    .' SUM OF X S = %',XTOT*100.

      RETURN

      END
C                    END OF SUBROUTINE PORT
C     ***************************************************************

C     ***************************************************************
      SUBROUTINE TRACKER (NUM,IREAD)
C     ***************************************************************
      INCLUDE 'COMSUC.F'

C ********   RESET THE RETURNS TO ORIGINAL STATE  ********************
C       DO 1300 J=1,NUM
C          DO 1300 I=1,NSTAT
C              RET(I,J)=RET(I,J)+ANIM(I)*TARGET
C              IF(I+NM-NSTAT-1.EQ.94)RET(I,J)=RET(I,J)*2.97
C 1300  CONTINUE

C ******      SET AVERAGES AND COVARIANCES TO ZERO  ******************
       DO 400 I=1,3
          AVE(I)=0.0
          DO 400 J=1,3
             COV(I,J)=0.0
 400  CONTINUE

C *** SET STAT ARRAY  1 = LIABILITY, 2 = PORTFOLIO, 3 = DIFFERENCES **
       DO 250 I=1,IREAD
          STAT(I,1)=ANIM(I)
          STAT(I,2)=PRET(I)
          STAT(I,3)=(PRET(I)-ANIM(I))
 250  CONTINUE

C *****       CALCULATE AVERAGES      ********************************
C *****       SET NSIM TO 2 FOR  STATISTICS IF NSIMS.LT.1     *********
       NSIM = NSIMS
       IF(NSIMS.LT.1) NSIM = 2
       DO 260 I=NSTAT+1,IREAD
          AVE(1)=AVE(1)+ANIM(I)/DBLE(NSIM)
          AVE(2)=AVE(2)+PRET(I)/DBLE(NSIM)
          AVE(3)=AVE(3)+(PRET(I)-ANIM(I))/DBLE(NSIM)
 260   CONTINUE

C *****       CALCULATE COVARIANCES  **********************************

       DO 950 I=1,3
          VAR(I)=0.0
          DO 950 K=NSTAT+1,IREAD
             VAR(I)=VAR(I)+(STAT(K,I)-AVE(I))**2/DBLE(NSIM-1)
 950   CONTINUE

C ******     CALCULATE THE COVARIANCE MATRIX'S UPPER OFF DIAGONAL ****

          DO 960 I=1,3
            DO 960 J=1,3
              DO 828 K=NSTAT+1,IREAD
              COV(I,J)=COV(I,J)+((STAT(K,I)-AVE(I))*(STAT(K,J)-AVE(J)))
 828          CONTINUE
              COV(I,J)=COV(I,J)/DBLE(NSIM-1)
               COV(J,I) = COV(I,J)
 960       CONTINUE

C *****       CALCULATE CORRELATIONS      ****************************
```

```
      DO 847 I=NSTAT,IREAD
          ISTAT = I-NSTAT-1
          WRITE(10,328)ISTAT+NM,ANIM(I),PRET(I)
  328     FORMAT(1X,I5,7X,F7.3,10X,F7.3)
  847 CONTINUE
  837 CONTINUE

C *****       WRITE STATISTICS  BASED ON SIMULATIONS MONTHS  ***********

      WRITE(10,*)
       WRITE(10,*)'***********      STATISTICAL SUMMARY      ***********'
       WRITE(10,985)NM,NM+NSIMS-1
  985  FORMAT(/,'     STATISTICS BASED ON MONTHS ',I4,' THROUGH',I4)

C *****       WRITE ALPHA,BETA,STDERR,CORREL,AND R-SQUARED   ***********

       WRITE(10,*)
       WRITE(10,987)'ALPHA',ALPHA,'ANNUAL',ALPHA*1200
       WRITE(10,989)'BETA',BETA
       WRITE(10,988)'STD ERR',STDERR,STDERR*100
       WRITE(10,989)'CORRELATION',COREL(2,1)
       WRITE(10,988)'R-SQUARED',RSQ,RSQ*100
  987  FORMAT(1X,A12,10X,F10.6,A8,F10.2,' %')
  988  FORMAT(1X,A12,10X,F10.6,8X,F10.2,' %')
  989  FORMAT(1X,A12,10X,F10.6)

C *****       WRITE AVERAGES AND VARIANCES OF 1-LIAB, 2-PORT, 3-DIFFS **

      WRITE(10,*)
      WRITE(10,*)
      WRITE(10,*)'ANNUAL RETURNS:              MEAN                 STD DEV'
      WRITE(10,*)

      DO 990 I = 1,3
         AVE(I) = (AVE(I)*12)*100
         VAR(I) = ((VAR(I)*12)**.5)*100
  990 CONTINUE

      WRITE(10,916) 'LIABILITY',AVE(1),VAR(1)
      WRITE(10,916) 'PORTFOLIO',AVE(2),VAR(2)
      WRITE(10,916) 'DIFFERENCE',AVE(3),VAR(3)
  916 FORMAT(1X,3X,A11,9X,F9.2,' %',10X,F9.2,' %')

C *****       WRITE PARAMETERS FOR THE RUN   ***************************

      WRITE(10,*)
      WRITE(10,*)
      WRITE(10,*)'      PARAMETERS FOR THIS RUN WERE: '
      WRITE(10,*)
      WRITE(10,101) TITLE
      WRITE(10,102) FILEOUT

      DO 951 I=1,3
         DO 951 J=1,I
         IF(VAR(I).LE. 0.0 .OR. VAR(J).LE. 0.0) GO TO 951
          COREL(I,J)=COV(I,J)/(VAR(I)**.5*VAR(J)**.5)
  951 CONTINUE
C *****       CALCULATE CUMULATIVE RETURNS     ************************
      PRET(NSTAT)=100
      ANIM(NSTAT)=100
      DO 569 I=NSTAT+1,IREAD
         XX=PRET(I)
         YY=ANIM(I)
         PRET(I)=PRET(I-1)*(1+XX)
         ANIM(I)=ANIM(I-1)*(1+YY)
  569 CONTINUE

       IF(VAR(1).NE. 0.0)   BETA = COV(1,2)/VAR(1)
       ALPHA = AVE(2) - BETA*AVE(1)

       SST =    0.0
       SSE =    0.0
       DO 952 I = NSTAT+1,IREAD
          SSE = SSE + (ALPHA+BETA*STAT(I,1)-STAT(I,2))**2
          SST = SST + (STAT(I,2)-AVE(2))**2
  952  CONTINUE

       IF(NSIMS.GT.2) STDERR = (SSE/DBLE(NSIMS-2))**.5
       IF(SST.NE.0.0) RSQ = 1 - SSE/SST

C*********************************************************************
C *****       BEGIN WRITING THE TRACKER OUTPUT     ********************

  318  WRITE(10,*)' TRACKER OUTPUT FILE '
       WRITE(10,*)
       WRITE(10,*)'   MONTH      LIA        PORT        DIF'
       WRITE(10,*)

C *****       WRITE MONTH, LIABILITY RET, PORTFOLIO RET, DIFFERENCE **** .
      DO 700 I=NSTAT+1,IREAD
          ISTAT = I-(NSTAT+1)
          WRITE(10,612)ISTAT+NM,(STAT(I,J),J=1,3)
  612     FORMAT(1X,3X,I4,3F13.10)
  700 CONTINUE

C *****       WRITE CUMULATIVE RETURNS      ***************************

      WRITE(10,*)
       WRITE(10,886)
  886  FORMAT(1X,'CUMMULATIVE VALUES OF LIABILITIES AND ASSETS'/,
     ./,' MONTH    LIABILTIES      PORTFOLIO',/)
```

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```
      SUBROUTINE BAL (NUM)
C     ***************************************************************
      INCLUDE 'COMSUC.F'
      DIMENSION CC(ND,2)
      INTEGER BUY(ND),SELL(ND)

      VNEW = 0.0
      VOLD = 0.0

      DO 10 I=1,NUM
         CC(I,1) = 0.0
         CC(I,2) = 0.0
         DO 20 J=1,NUM
            CC(I,1) = CC(I,1)+X(J)*2.0*A(I,J)
            VNEW = VNEW+X(I)*X(J)*A(I,J)
            CC(I,2) = CC(I,2)+OLDWT(J)*2.0*A(I,J)
            VOLD = VOLD+OLDWT(I)*OLDWT(J)*A(I,J)
20       CONTINUE
10    CONTINUE
C *******      DELTA IS THE PERCENTAGE IMPROVEMENT IN VARIANCE *******
      DELTA = (VOLD - VNEW)/VNEW
      DELTA = DELTA * 10000.
C ******** IF THE OLD VARIANCE IS ZERO USE THE NEW PARTIALS TO SORT **
      KVAR = 2
      IF (VOLD.EQ.0) KVAR = 1

      IBUY = 0
      ISELL = 0
      TURNOV = 0.0

      DO 30 I = 1,NUM
        IF((X(I)-OLDWT(I)).GT.0.001) THEN
          IBUY = IBUY + 1
          BUY(IBUY) = I
        ELSE IF((X(I)-OLDWT(I)).LT.-0.001) THEN
          ISELL = ISELL +1
          SELL(ISELL) = I
        END IF
      TURNOV = TURNOV + ABS(X(I)-OLDWT(I))
30    CONTINUE

C ******  SORT BASED ON PARTIALS ***************************************
C ******     SORT THE BUYS     ***************************************
      DO 40 I = 1,IBUY-1
         DO 50 J = I+1,IBUY
         IF( CC(BUY(J),KVAR).GT.CC(BUY(I),KVAR)) THEN
           ITEMP = BUY(I)
           BUY(I) = BUY(J)
           BUY(J) = ITEMP
         END IF
50       CONTINUE
40    CONTINUE
```

```
      WRITE(10,103) LIABIN
      WRITE(10,104) STOCKIN
      WRITE(10,105) BONDIN
      WRITE(10,106) NMSAVE
      WRITE(10,107) NSIMS
      WRITE(10,108) NSTOCKS
      WRITE(10,109) NBONDS
      WRITE(10,110) IDUMMY
      WRITE(10,111) STOCKMIN
      WRITE(10,112) YIMAX
      WRITE(10,113) SMAX
      WRITE(10,114) NSTAT
      WRITE(10,115) NRETS
      WRITE(10,116) BULL1
      WRITE(10,117) TARG1
      WRITE(10,118) TURN1

101   FORMAT(1X,' 1) SPANNING RUN TITLE          ', A30)
102   FORMAT(1X,' 2) OUTPUT FILENAME             ', A30)
103   FORMAT(1X,' 3) LIABILITY STREAM FILE       ', A30)
104   FORMAT(1X,' 4) STOCK RETURN FILE           ', A30)
105   FORMAT(1X,' 5) BOND RETURN FILE            ', A30)
106   FORMAT(1X,' 6) MONTH SIMULATION BEGINS     ',  I6)
107   FORMAT(1X,' 7) NUMBER OF MONTHS SIMULATED  ',  I6)
108   FORMAT(1X,' 8) NUMBER OF STOCKS            ',  I6)
109   FORMAT(1X,' 9) NUMBER OF BONDS             ',  I6)
110   FORMAT(1X,'10) STOCKS TO READ PAST         ',  I6)
111   FORMAT(1X,'11) MINIMUM STOCK HOLDING    % ',F6.2)
112   FORMAT(1X,'12) MAXIMUM INDUSTRY HOLDING % ',F6.2)
113   FORMAT(1X,'13) MAXIMUM STOCK HOLDING    % ',F6.2)
114   FORMAT(1X,'14) NSTAT                       ',  I6)
115   FORMAT(1X,'15) NRETS                       ',  I6)
116   FORMAT(1X,'16) BULLET                      ',F6.2)
117   FORMAT(1X,'17) TARGET                      ',F6.2)
118   FORMAT(1X,'18) TURNOVER FACTOR             ',F6.2)

C *****      WRITE HISTORICAL DATA USED TO MAKE RUN   *****************
      WRITE(10,*)
      WRITE(10,*)' PORTFOLIO CONSTRUCTED UPON THE FOLLOWING DATA:'
      WRITE(10,*)
      WRITE(10,*)'   MONTH      LIA         PORT        DIF'
      WRITE(10,*)
      DO 300 I=1,NSTAT
         WRITE(10,612)I+NM-(NSTAT+1),(STAT(I,J),J=1,3)
300   CONTINUE

      RETURN

      END
C                          END OF SUBROUTINE TRACKER
C     ***************************************************************
C     ***************************************************************
```

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```
      XOLD = OLDWT(SELL(I))*100
      XNEW = X(SELL(I))*100
      WRITE(10,101) XOLD,XNEW,XNEW-XOLD,CC(SELL(I),KVAR)*1000,
     &              ISIC(SELL(I)),IDC(SELL(I)),NAME(SELL(I))
90    CONTINUE

101   FORMAT(1X,4F7.3,I4,4X,A9,2X,A30)
102   FORMAT(1X,80A1)

C *******   WRITE OUT THE  INDUSTRY  WEIGHTS   ************************
      CALL INDUST
      WRITE(10,*)
      WRITE(10,*)
      WRITE(10,*)'          *** INDUSTRY WEIGHTINGS ***'
      WRITE(10,102)('*',I=1,78)
      WRITE(10,*)' CODE          INDUSTRY                    WEIGHT'
      WRITE(10,102)('*',I=1,78)

      DO 133 I = 1,99
         CUM(I) = 0.0
         DO 134 J = 1,NUM
            IF (ISIC(J).EQ.I) CUM(I) = CUM(I) + X(J)
134      CONTINUE
      IF (CUM(I).GT. 0.001) WRITE(10,135) I,SIC(I),CUM(I)*100.
135   FORMAT(1X,I5,3X,A30,F10.2,' %')
133   CONTINUE

      SUMWGHT = 0.0
      DO 136 I = 1,NUM
        SUMWGHT = SUMWGHT + X(I)
136   CONTINUE
      WRITE(10,137)'                      TOTAL   =   ',SUMWGHT*100
137   FORMAT(1X,A38,F10.2,' %')

      DO 138 I = 1,4
         WRITE(10,102)(' ',I=1,78)
138   CONTINUE
      CLOSE(10)

      RETURN
      END
C*****************     END OF SUBROUTINE  BAL       ******************
C   ***************************************************************
      SUBROUTINE INDUST
C   ***************************************************************

      INCLUDE 'COMSUC.F'

      SIC(1) = 'AGRICULTURAL PRODUCTION-CROPS'
      SIC(2) = 'AGRICULTURAL PROD.-LIVESTOCK'
      SIC(7) = 'AGRICULTURAL SERVICES'

C ******    SORT THE SELLS   ****************************************
      DO 60 I = 1,ISELL-1
         DO 70 J = I+1,ISELL
      TEST = CC(SELL(J),KVAR) - CC(SELL(I),KVAR)
         IF (TEST .LT. 0) THEN
           ITEMP = SELL(I)
           SELL(I) = SELL(J)
           SELL(J) = ITEMP
         END IF
70       CONTINUE

60    CONTINUE

      WRITE(10,*)
      WRITE(10,*)'                TURNOVER = ',TURNOV*50,' %'
      WRITE(10,*)
      WRITE(10,*)'VARIANCE AT  OLD  WEIGHTS = ',VOLD*10000
      WRITE(10,*)'VARIANCE AT  NEW  WEIGHTS = ',VNEW*10000
      WRITE(10,*)'                   DELTA = ',DELTA/100,' %'
      WRITE(10,*)
      WRITE(10,*)

C ************        WRITE THE BUYS       ********************

      WRITE(10,*)'                                ***    BUY    ***'
      WRITE(10,102)('*',I=1,78)
      WRITE(10,*)'    ***  WEIGHTS ***  SPAN   SIC',
     &'      SYMBOL    SECURITY'
      WRITE(10,*)'    OLD   NEW  DELTA  SENSIT CODE',
     &'  IDC TICK   NAME'
      WRITE(10,102)('*',I=1,78)

      DO 80 I = 1,IBUY
      XOLD = OLDWT(BUY(I))*100
      XNEW = X(BUY(I))*100
      WRITE(10,101) XOLD,XNEW,XNEW-XOLD,CC(BUY(I),KVAR)*1000,
     &              ISIC(BUY(I)),IDC(BUY(I)),NAME(BUY(I))
80    CONTINUE

      WRITE(10,*)
      WRITE(10,*)
      WRITE(10,*)
C ************        WRITE THE SELLS      ********************
      WRITE(10,*)'                                ***    SELL    ***'
      WRITE(10,102)('*',I=1,78)
      WRITE(10,*)'    ***  WEIGHTS ***  SPAN   SIC',
     &'      SYMBOL    SECURITY'
      WRITE(10,*)'    OLD   NEW  DELTA  SENSIT CODE',
     &'  IDC TICK   NAME'
      WRITE(10,102)('*',I=1,78)

      DO 90 I = 1,ISELL
```

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```
      SIC(8) = 'FORESTRY'
      SIC(9) = 'FISHING HUNTING AND TRAPPING'
      SIC(10) = 'METAL MINING'
      SIC(11) = 'ANTHRACITE MINING'
      SIC(12) = 'BITUMINOUS COAL & LIGNITE MIN.'
      SIC(13) = 'OIL & GAS EXTRACTION'
      SIC(14) = 'MIN. & QUARRY. OF NONMET. MIN.'
      SIC(15) = 'BUILD. CONST.-G. C. & O. B.'
      SIC(16) = 'CONST. OTH THAN B.C.-G.C.'
      SIC(17) = 'CONST.-SPEC. TRADE CONT.'
      SIC(20) = 'FOOD KINDRED PRODUCTS'
      SIC(21) = 'TOBACCO MANUFACTURERS'
      SIC(22) = 'TEXTILE MILL PRODUCTS'
      SIC(23) = 'APP. & OTH. FIN. PROD. MFFAOSM'
      SIC(24) = 'LUMBER & WOOD PROD. EX. FURN.'
      SIC(25) = 'FURNITURE AND FIXTURES'
      SIC(26) = 'PAPER AND ALLIED PRODUCTS'
      SIC(27) = 'PRINTING PUBLISHING AND A.P.'
      SIC(28) = 'CHEMICAL AND ALLIED PROD.'
      SIC(29) = 'PETROLEUM REFIN. & REL. PROD.'
      SIC(30) = 'RUBBER AND MISC. PLAST. PROD.'
      SIC(31) = 'LEATHER & LEATHER PRODUCTS'
      SIC(32) = 'STONE CLAY GLASS & CONC. PROD.'
      SIC(33) = 'PRIMARY METAL INDUSTRIES'
      SIC(34) = 'FAB. METAL PROD. EX. M.&T.E.'
      SIC(35) = 'MACHINERY EXCEPT ELECTRICAL'
      SIC(36) = 'ELE. AND ELE. MACH.'
      SIC(37) = 'TRANSPORTATIONS EQUIPMENT'
      SIC(38) = 'MEAS. ANAL. & CONT. INST. ETC.'
      SIC(39) = 'MISC. MANUFACTURING IND.'
      SIC(40) = 'RAILROAD TRANS.'
      SIC(41) = 'LOC. AND SUB. TRANS. & HPT'
      SIC(42) = 'MOTOR FREIGHT TRANS. AND WARE.'
      SIC(43) = 'U.S. POSTAL SERVICE'
      SIC(44) = 'WATER TRANSPORTATION'
      SIC(45) = 'TRANSPORTATION BY AIR'
      SIC(46) = 'PIPE LINES EX. NATURAL GAS'
      SIC(47) = 'TRANSPORTATION SERVICES'
      SIC(48) = 'COMMUNICATION'
      SIC(49) = 'ELECTRIC GAS AND SANIT. SERV.'
      SIC(50) = 'WHOLESALE TRADE-DURABLE GOODS'
      SIC(51) = 'WHOLESALE TRADE-NONDUR. GOODS'
      SIC(52) = 'BUILDING MAT. HARD. GAR. SUPP.'
      SIC(53) = 'GENERAL MERCH. STORES'
      SIC(54) = 'FOOD STORES'
      SIC(55) = 'AUTOMOTIVE DEAL AND GAS. SS'
      SIC(56) = 'APPAREL AND ACCESS. STORES'
      SIC(57) = 'HOME FURN. AND EQUIP. STORES'
      SIC(58) = 'EATING AND DRINKING PLACES'
      SIC(59) = 'MISCELLANEOUS RETAIL'
      SIC(60) = 'BANKING'
      SIC(61) = 'CRED. AGEN. OTH. THAN BANKS.'
      SIC(62) = 'SEC. AND COMM. BROK. DEEXSE'
      SIC(63) = 'INSURANCE CARRIERS'
      SIC(64) = 'INS. AGENTS BROK. SERV.'
      SIC(65) = 'REAL ESTATE'
      SIC(66) = 'COMB. RE INS. LOANS & LAW OFF.'
      SIC(67) = 'HOLD. AND OTHER INV. COMP.'
      SIC(70) = 'HOTELS ROOM. HOUSES CAMP AOLP'
      SIC(72) = 'PERSONAL SERVICES'
      SIC(73) = 'BUSINESS SERVICES'
      SIC(75) = 'AUTO. REPAIR SERV. AND GAR.'
      SIC(76) = 'MISC. REPAIR SERVICES'
      SIC(78) = 'MOTION PICTURES'
      SIC(79) = 'AMUSE. AND REC. SERV. EX. MP'
      SIC(80) = 'HEALTH SERVICES'
      SIC(81) = 'LEGAL SERVICES'
      SIC(82) = 'EDUCATIONAL SERVICES'
      SIC(83) = 'SOCIAL SERVICES'
      SIC(84) = 'MUSEUM ART GALL. BOT. Z.G.'
      SIC(86) = 'NONPROFIT MEM. ORGAN.'
      SIC(89) = 'MISCELLANEOUS SERVICES'
      SIC(91) = 'EXEC. LEG. & GOVT EX. FIN.'
      SIC(92) = 'JUSTICE PUBLIC SAFETY'
      SIC(93) = 'PUB. FIN. TAX. & MON. POLICY'
      SIC(94) = 'ADMIN. OF HUMAN RES. PROGRAMS'
      SIC(95) = 'ADMIN. OF QUAL. & HOUS. PROG.'
      SIC(96) = 'ADMIN. OF ECONOMIC PROGRAMS'
      SIC(97) = 'NATIONAL SEC. & INTL AFFAIRS'
      SIC(99) = 'NONCLASSIFIABLE ESTABLISHMENTS'
      RETURN
      END
C*****************     END OF SUBROUTINE  INDUST     *****************
C  UPDATED December 6, 1988
*************************************************************************
      SUBROUTINE INTRO
*************************************************************************
* **
* **   THIS ROUTINE INTRODUCES THE SPANNING PROGRAM AND
* **   ASKS FOR SCREEN OR FILE INPUT OPTION
* **
      INCLUDE 'COMSUC.F'

      INTEGER RESPON

      PARAMETER (MAXTXT = 50,LINES = 24)
      CHARACTER HEAD*(MAXTXT),LAST*(MAXTXT),OPTION(LINES)*(MAXTXT)

      HEAD = '      WELCOME  TO  THE  NISA  SPANNING  OPTIMIZER'

      NBROPT = 2
      OPTION (1) = 'SINGLE RUN WITH WEIGHTS IN FILE: OLD'
      OPTION (2) = 'UPDATE RUN WITH WEIGHTS CALCUATED FROM HOLDINGS'
```

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```
      WRITE(*,100)(' ',I = 1,5)

      OPEN (8,FILE = PAST, STATUS = 'OLD', ERR =  10)
      READ(8,101)TITLE
      READ(8,101)FILEOUT
      READ(8,101)LIABIN
      READ(8,101)STOCKIN
      READ(8,101)BONDIN
      READ(8,102)NMSAVE
      READ(8,102)NSIMS
      READ(8,102)NSTOCKS
      READ(8,102)NBONDS
      READ(8,102)IDUMMY
      READ(8,103)STOCKMIN
      READ(8,103)YIMAX
      CLOSE (8)
      RETURN

10    CONTINUE
* **     GIVE OPTION TO READ FROM SCREEN WITHOUT DUMPING OUT OF
* **     PROGRAM OR TO READ FROM DIFFERENT FILE NAME

      HEAD = '... WARNING: THE PAST DATA FILE DOES NOT EXIST'
      LAST =                          ( CTRL-C TO ABORT )'
      NBROPT = 2
      OPTIONS(1) = 'INPUT NEW NAME FOR PAST DATA FILE'
      OPTIONS(2) = 'READ IN NEW DATA FROM SCREEN '

20    CALL MENU (LINES,HEAD,LAST,NBROPT,OPTIONS,IRESPON)

      IF ( IRESPON.EQ.1) THEN
         WRITE(*,100)(' ',I = 1,5)
         WRITE(*,104)
         READ(*,'(A30)',END = 20,ERR = 20) PAST
         GO TO 5

      ELSE IF (IRESPON.EQ.2) THEN
         CALL REDSCRN
         RETURN

      END IF

      RETURN

100   FORMAT('0',A1)
101   FORMAT(A35)
102   FORMAT(I4)
103   FORMAT(F7.2)
104   FORMAT(' NAME FOR PAST DATA FILE --- ',$)
```

```
      LAST = ' '

10    CALL MENU(LINES,HEAD,LAST,NBROPT,OPTION,RESPON)

      IF (RESPON.EQ.1) THEN
         IHOLD = 0
         CALL REDPAST

      ELSE IF (RESPON.EQ.2) THEN
         IHOLD = 1
         CALL REDPAST

      ELSE
         WRITE(*,*)'NO OPTION SELECTED - PLEASE TRY AGAIN'
         GO TO 10

      END IF

C     RETURN
      END
****************     END OF SUBROUTINE  INTRO     ******************
*****************************************************************
      SUBROUTINE REDPAST
*****************************************************************
C     TITLE          = TITLE FOR THIS RUN
C     FILEOUT        = OUTPUT FILE
C     LIABIN         = LIABILITY RETURNS FILE
C     STOCKIN        = STOCK RETURNS FILE
C     BONDIN         = BOND RETURNS FILE
C     NMSAVE         = FIRST MONTH OF SIMULATION
C     NSIMS          = NUMBER OF MONTHS TO SIMULATE
C     NSTOCKS        = NUMBER OF STOCK TO SEND TO OPTIMIZER
C     NBONDS         = NUMBER OF BONDS TO SEND TO OPTIMIZER
C     IDUMMY         = NUMBER OF STOCKS TO READ PAST IN STOCKIN
C     STOCKMIN       = MINIMUM HOLDING IN STOCKS
C     YIMAX          = INDUSTRY MAXIMUM HOLDING
C     SMAX           = SECURITY MAXIMUM HOLDING
C     BULLET         = CLIMBING FACTOR
C     TARGET         = ADJUSTMENT FACTOR FOR TARGET
C     TURN           = TURNOVER FACTOR
      INCLUDE 'COMSUC.F'

      PARAMETER (MAXTXT = 50,LINES = 24)

      CHARACTER HEAD*(MAXTXT),LAST*(MAXTXT),OPTIONS(LINES)*(MAXTXT)
      CHARACTER*30 PAST
* **
* **     INITIALIZE READ IN FILE: PAST  =  'PAST.DAT'
* **
      PAST = 'PAST.DAT'
      WRITE(*,100)(' ',I = 1,5)
      WRITE(*,*)'   READING PAST DATA.....'
```

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```
 105    FORMAT(' 5) ENTER BOND RETURNS FILE NAME       - ',$)
        READ(*,'(A30)',END = 5,ERR = 5) BONDIN
        IF (BONDIN.EQ.' ')BONDIN = 'BONDS.PRN'
        WRITE(*,*)

 6      WRITE(*,*)' 6) ENTER YEAR AND MONTH TO BEGIN       '
        WRITE(*,106)
 106    FORMAT('     SIMULATION (e.g. FEB 1987 = 8702)  - ',$)
        READ(*,*,END = 6,ERR = 6) NMSAVE
        WRITE(*,*)

 7      WRITE(*,107)
 107    FORMAT(' 7) ENTER NUMBER OF MONTHS TO SIMULATE - ',$)
        READ(*,*,END = 7,ERR = 7) NSIMS
        WRITE(*,*)

 8      WRITE(*,108)
 108    FORMAT(' 8) ENTER NUMBER OF  STOCKS  TO USE    - ',$)
        READ(*,*,END = 8,ERR = 8) NSTOCKS
        WRITE(*,*)

 9      WRITE(*,109)
 109    FORMAT(' 9) ENTER NUMBER OF  BONDS  TO USE     - ',$)
        READ(*,*,END = 9,ERR = 9) NBONDS
        WRITE(*,*)

 10     WRITE(*,110)
 110    FORMAT('10) ENTER NUMBER OF STOCKS READ PAST   - ',$)
        READ(*,*,END =10,ERR = 10) IDUMMY
        WRITE(*,*)

 11     WRITE(*,111)
 111    FORMAT('11) ENTER MINIMUM STOCK HOLDING        - % ',$)
        READ(*,*,END = 11,ERR = 11) STOCKMIN
        WRITE(*,*)

 12     WRITE(*,112)
 112    FORMAT('12) ENTER MAXIMUM INDUSTRY HOLDING     - % ' ,$)
        READ(*,*,END = 12,ERR = 12) YIMAX
        WRITE(*,*)

        RETURN

 100    FORMAT(A35)

        END
*************      END OF SUBROUTINE  REDSCRN    ******************

*****************************************************************
      SUBROUTINE MODIFY
*****************************************************************
* **
```

```
      END
*************      END OF SUBROUTINE  REDPAST    ******************

*****************************************************************
      SUBROUTINE REDSCRN
*****************************************************************

      TITLE      - TITLE FOR THIS RUN
      FILEOUT    - OUTPUT FILE
      LIABIN     - LIABILITY RETURNS FILE
      STOCKIN    - STOCK RETURNS FILE
      BONDIN     - BOND RETURNS FILE
      NMSAVE     - FIRST MONTH OF SIMULATE
      NSIMS      - NUMBER OF MONTHS TO SIMULATE
      NSTOCKS    - NUMBER OF STOCK TO SEND TO OPTIMIZER
      NBONDS     - NUMBER OF BONDS TO SEND TO OPTIMIZER
      IDUMMY     - NUMBER OF STOCKS TO READ PAST IN STOCKIN
      STOCKMIN   - MINIMUM HOLDING IN STOCKS
      YIMAX      - INDUSTRY MAXIMUM HOLDING

      INCLUDE 'COMSUC.F'

**      DEFAULT NAMES FOR STOCK AND BOND FILES
**      STOCKS.PRN     &   BONDS.PRN


      WRITE(*,113)(' ',I = 1,12)
 13   FORMAT('0',A1)

      WRITE(*,101)
 101  FORMAT(' 1) ENTER TITLE FOR SPANNING RUN       - ',$)
      READ(*,'(A30)',END = 1,ERR = 1) TITLE
      WRITE(*,*)

 2    WRITE(*,102)
 102  FORMAT(' 2) ENTER OUTPUT FILE NAME             - ',$)
      READ(*,'(A30)',END = 2,ERR = 2) FILEOUT
      WRITE(*,*)

 3    WRITE(*,103)
 103  FORMAT(' 3) ENTER LIABILITY RETURNS FILE NAME  - ',$)
      READ(*,'(A30)',END = 3,ERR = 3) LIABIN
      WRITE(*,*)

 4    WRITE(*,104)
 104  FORMAT(' 4) ENTER STOCK RETURNS FILE NAME      - ',$)
      READ(*,'(A30)',END = 4,ERR = 4) STOCKIN
      IF (STOCKIN.EQ.' ')STOCKIN = 'STOCKS.PRN'
      WRITE(*,*)

 5    WRITE(*,105)
```

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```
C*   THIS ROUTINE MODIFIES THE INPUT DATA IF NECESSARY
C*
      INCLUDE 'COMSUC.F'
      WRITE(*,100)(' ',I = 1,5)
      WRITE(*,*)'********    CURRENTLY SELECTED PARAMETERS    ********'
*************    DISPLAY SELECTED PARAMETERS    ********************
      CALL DISPLAY
      IRESPON = 0
      WRITE(*,120)
      READ(*,'(I2)',END = 20,ERR = 10) IRESPON
      IF(IRESPON.EQ.0) THEN
         RETURN
      ELSE IF (IRESPON .EQ. 1 ) THEN
01       WRITE(*,121)
         READ *,'(A30)',END = 201, ERR = 201) TITLE
      ELSE IF (IRESPON.EQ.2) THEN
02       WRITE(*,122)
         READ *,'(A30)',END = 202, ERR = 202) FILEOUT
      ELSE IF (IRESPON.EQ.3) THEN
03       WRITE(*,123)
         READ(*,'(A30)',END = 203, ERR = 203) LIABIN
      ELSE IF (IRESPON.EQ.4) THEN
204      WRITE(*,124)
         READ(*,'(A30)',END = 204, ERR = 204) STOCKIN
      ELSE IF (IRESPON.EQ.5) THEN
205      WRITE(*,125)
         READ(*,'(A30)',END = 205, ERR = 205) BONDIN
      ELSE IF (IRESPON.EQ.6) THEN
206      WRITE(*,126)
         READ(*,*,END = 206, ERR = 206) NMSAVE
      ELSE IF (IRESPON.EQ.7) THEN
207      WRITE(*,127)
         READ(*,*,END = 207, ERR = 207) NSIMS
      ELSE IF (IRESPON.EQ.8) THEN
208      WRITE(*,128)
         READ(*,*,END = 208, ERR = 208) NSTOCKS
      ELSE IF (IRESPON.EQ.9) THEN
209      WRITE(*,129)
         READ(*,*,END = 209, ERR = 209) NBONDS
      ELSE IF (IRESPON.EQ.10) THEN
210      WRITE(*,130)
         READ(*,*,END = 210, ERR = 210) IDUMMY
      ELSE IF (IRESPON.EQ.11) THEN
211      WRITE(*,131)
         READ(*,*,END = 211, ERR = 211) STOCKMIN
      ELSE IF (IRESPON.EQ.12) THEN
212      WRITE(*,132)
         READ(*,*,END = 212, ERR = 212) YIMAX
      ELSE IF (IRESPON.EQ.13) THEN
213      WRITE(*,133)
         READ(*,*,END = 213, ERR = 213) SMAX
      ELSE IF (IRESPON.EQ.14) THEN
214      WRITE(*,134)
         READ(*,*,END = 214, ERR = 214) NSTAT
      ELSE IF (IRESPON.EQ.15) THEN
215      WRITE(*,135)
         READ(*,*,END = 215, ERR = 215) NRETS
      ELSE IF (IRESPON.EQ.16) THEN
216      WRITE(*,136)
         READ(*,*,END = 216, ERR = 216) BULLET
      ELSE IF (IRESPON.EQ.17) THEN
217      WRITE(*,137)
         READ(*,*,END = 217, ERR = 217) TARGET
      ELSE IF (IRESPON.EQ.18) THEN
218      WRITE(*,138)
         READ(*,*,END = 218, ERR = 218) TURN
      END IF
      GO TO 10
 20   RETURN
100   FORMAT('0',A1)
120   FORMAT('0',' ENTER NUMBER TO MODIFY   <ENTER> TO CONTINUE: ',$)
121   FORMAT('0',' ENTER SPANNING RUN TITLE                      ',$)
122   FORMAT('0',' ENTER FILENAME FOR OUTPUT                     ',$)
123   FORMAT('0',' ENTER LIABILITY STREAM FILE                   ',$)
124   FORMAT('0',' ENTER STOCK RETURN FILE                       ',$)
125   FORMAT('0',' ENTER BOND RETURN FILE                        ',$)
126   FORMAT('0',' ENTER MONTH TO BEGIN SIMULATION               ',$)
127   FORMAT('0',' ENTER NUMBER OF MONTHS TO SIMULATE            ',$)
```

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```
107   FORMAT(1X,' 7) NUMBER OF MONTHS TO SIMULATE          ',  I6)
108   FORMAT(1X,' 8) NUMBER OF STOCKS                      ',  I6)
109   FORMAT(1X,' 9) NUMBER OF BONDS                       ',  I6)
110   FORMAT(1X,'10) STOCKS TO READ PAST                   ',  I6)
111   FORMAT(1X,'11) MINIMUM STOCK HOLDING              % ',F6.2)
112   FORMAT(1X,'12) MAXIMUM INDUSTRY HOLDING           % ',F6.2)
113   FORMAT(1X,'13) MAXIMUM SINGLE STOCK HOLDING       % ',F6.2)
114   FORMAT(1X,'14) NSTAT                                 ',  I6)
115   FORMAT(1X,'15) NRETS                                 ',  I6)
116   FORMAT(1X,'16) BULLET                                ',F6.2)
117   FORMAT(1X,'17) TARGET                                ',F6.2)
118   FORMAT(1X,'18) TURNOVER FACTOR                       ',F6.2)
      END
**********      END OF SUBROUTINE  DISPLAY     ******************

**********************************************************************
      SUBROUTINE SAVDAT
**********************************************************************
* **
* **   THIS ROUTINE SAVE THE FILE FOR LATER USE
* **

      INCLUDE 'COMSUC.F'

      OPEN(8,FILE = 'PAST.DAT',STATUS = 'OLD')
      WRITE(8,101)TITLE
      WRITE(8,101)FILEOUT
      WRITE(8,101)LIABIN
      WRITE(8,101)STOCKIN
      WRITE(8,101)BONDIN
      WRITE(8,102)NMSAVE
      WRITE(8,102)NSIMS
      WRITE(8,102)NSTOCKS
      WRITE(8,102)NBONDS
      WRITE(8,102)IDUMMY
      WRITE(8,103)STOCKMIN
      WRITE(8,103)YIMAX
      CLOSE (8)

      RETURN

100   FORMAT('0',A1)
101   FORMAT(A35)
102   FORMAT(I4)
103   FORMAT(F7.2)
104   FORMAT('+',A50)

      END

******************      END OF SUBROUTINE  SAVDAT     ******************

C**********************************************************************
```

```
128   FORMAT('0',' ENTER NUMBER OF STOCKS                  ',$)
129   FORMAT('0',' ENTER NUMBER OF BONDS                   ',$)
130   FORMAT('0',' ENTER STOCKS TO READ PAST               ',$)
131   FORMAT('0',' ENTER MINIMUM TOTAL STOCK HOLDING    % ',$)
132   FORMAT('0',' ENTER MAXIMUM INDUSTRY HOLDING       % ',$)
133   FORMAT('0',' ENTER MAXIMUM SINGLE STOCK HOLDING   % ',$)
134   FORMAT('0',' ENTER NSTAT                             ',$)
135   FORMAT('0',' ENTER NRETS                             ',$)
136   FORMAT('0',' ENTER BULLET                            ',$)
137   FORMAT('0',' ENTER TARGET                            ',$)
138   FORMAT('0',' ENTER TURNOVER FACTOR                   ',$)
      END

******************      END OF SUBROUTINE  MODIFY     ******************
**********************************************************************
      SUBROUTINE DISPLAY
**********************************************************************
* **
* **   THIS ROUTINE DISPLAYS SELECTED PARAMETERS FOR SPANNING RUN
* **

      INCLUDE 'COMSUC.F'

      WRITE(*,100)
      WRITE(*,101) TITLE
      WRITE(*,102) FILEOUT
      WRITE(*,103) LIABIN
      WRITE(*,104) STOCKIN
      WRITE(*,105) BONDIN
      WRITE(*,106) NMSAVE
      WRITE(*,107) NSIMS
      WRITE(*,108) NSTOCKS
      WRITE(*,109) NBONDS
      WRITE(*,110) IDUMMY
      WRITE(*,111) STOCKMIN
      WRITE(*,112) YIMAX
      WRITE(*,113) SMAX
      WRITE(*,114) NSTAT
      WRITE(*,115) NRETS
      WRITE(*,116) BULLET
      WRITE(*,117) TARGET
      WRITE(*,118) TURN

      RETURN

100   FORMAT('0',A1)
101   FORMAT(1X,' 1) SPANNING RUN TITLE                  ', A30)
102   FORMAT(1X,' 2) OUTPUT FILENAME                     ', A30)
103   FORMAT(1X,' 3) LIABILITY STREAM FILE               ', A30)
104   FORMAT(1X,' 4) STOCK RETURN FILE                   ', A30)
105   FORMAT(1X,' 5) BOND RETURN FILE                    ', A30)
106   FORMAT(1X,' 6) MONTH TO BEGIN SIMULATION           ',  I6)
```

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```
      WRITE(*,*) LAST
* **
* **   BLANK OUT REST OF SCREEN
      DO 25 I = 1,IMAX
25    WRITE(*,*)' '
* **
* **   REQUEST RESPONSE
      WRITE(*,*)' '
      WRITE(*,*)' '
30    WRITE(*,999)
999   FORMAT(' SELECT NUMBER OF OPTION ---> ',$)
* **   RESPONSE SET TO ZERO IN CASE OF CARRIAGE RETURN
      RESPON = 0
      READ(*,'(I2)',END = 40,ERR = 5) RESPON
      IF (RESPON.LT.0.OR.RESPON.GT.NBROPT) THEN
         WRITE(*,*)' OPTION OUT OF RANGE'
         GO TO 30
      END IF
40    RETURN
      END
C*************************     END OF SUBROUTINE  MENU      ******************
*****************************************************************************

      SUBROUTINE QUAD1 (A,KT,RHS,COST,QUAD,INPUT,TOL,TITLE,PFILE,
     *   OBJ,X,RC,DUAL,SLK,IOUT,WS)
C
C           SUBROUTINE QUADPR FOR QUADRATIC PROGRAMMING PROGRAMS
C
C           QUADPR MINIMIZES OR MAXIMIZES  COST*X + X*QUAD*X
C                  SUBJECT TO     A*X + KT*'SLACK' = RHS
C                                            X .GE. 0.
C                  (KT(I)=-1,0,+1 IF I-TH CONSTRAINT IS .GE.,.EQ.,.LE.)
C                  THE OBJECTIVE FUNCTION SHOULD BE CONVEX (CONCAVE)
C                  FOR MINIMIZATION (MAXIMIZATION) PROBLEMS.
C                  THIS MEANS THE SYMMETRIC MATRIX QUAD+QUAD(TRANSPOSE)
C                  SHOULD BE NONNEGATIVE (NONPOSITIVE) DEFINITE
C                  FOR MINIMIZATION (MAXIMIZATION) PROBLEMS.
C
C     CALLING SEQUENCE ...
C     CALL QUADPR (A,KT,RHS,COST,QUAD,INPUT,TOL,TITLE,PFILE,
C    *   OBJ,X,RC,DUAL,SLK,IOUT,WS)
C
C     IN WHAT FOLLOWS, MO = NO. OF CONSTRAINTS, NO = NO. OF VARIABLES,
C     DIMENSION SIZES GIVEN ARE THE MINIMUM REQUIRED.
C
C A      --- MO X NO - CONSTRAINT MATRIX
C KT     --- MO-VECTOR OF CONSTRAINT TYPES,  -1,0,+1 MEAN .GE.,.EQ.,.LE.
C            RESPECTIVELY
C RHS    --- MO-VECTOR OF RIGHT-HAND-SIDE VALUES
C COST   --- NO-VECTOR OF LINEAR COSTS
C QUAD   --- NO X NO MATRIX OF QUADRATIC COSTS
```

```
      SUBROUTINE MENU (LINES,HEADER,LAST,NBROPT,OPTION,RESPON)
C*****************************************************************************
* **
* **   PURPOSE: TO PRINT A MENU AND READ RESPONSE
* **
* **
* **
* **   VARIABLE DEFINITIONS
* **   LINES        LINESIZE OF SCREEN
* **   HEADER       TITLE LINE FOR MENU
* **   LAST         LAST LINE OF MENU
* **   NBROPT       NUMBER OF OPTIONS
* **   OPTION       LIST OF OPTIONS
* **                DIMENSIONED OPTION(*)*(*) SO LENGTH
* **                OF CHARACTER STRINGS AND ARRAY SENT BY
* **                CALLING PROGRAM
* **   RESPON       NUMERIC RESPONSE
* **   I            MISCELLANEOUS INDEX
* **   IMAX         NUMBER OF BLANK LINES, TOP AND BOTTOM
* **
* **
* **   OVERALL SPECIFICATIONS
      IMPLICIT REAL (A-Z)
      INTEGER MAXTXT
      PARAMETER (MAXTXT = 50)
* **
* **   CALL SPECIFICATIONS
      CHARACTER OPTION(*)*(MAXTXT),HEADER*(MAXTXT),LAST*(MAXTXT)
      INTEGER NBROPT,RESPON,LINES
* **
* **   LOCAL SPECIFICATIONS
      INTEGER I,IMAX
* **
* **
* **   PRINT BLANK UPPER SCREEN
      IMAX = (LINES-NBROPT-7)/2+1
      IF (IMAX.LT.0) THEN
         WRITE(*,*)'TOO MANY OPTIONS TO FIT SCREEN SIZE'
         STOP
      END IF
5     DO 10 I = 1,IMAX
10    WRITE(*,*)'
* **
* **   PRINT MENU
      WRITE(*,*)HEADER
      WRITE(*,*)' '

      DO 20 I = 1,NBROPT
      WRITE(*,'(1X,I2,2H) ,$)') I
      WRITE(*,*)OPTION(I)
20    CONTINUE
```

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```
C
C WS     --- WORK SPACE ARRAY OF SIZE AT LEAST
C            2*(MO+NO)**2 + 12*(MO+NO) + 16 IF ANY EQUALITY CONSTRAINTS
C            ARE PRESENT OR  2*(MO+NO)**2 +  8*(MO+NO) + 6
C            IF ALL CONSTRAINTS ARE INEQUALITIES.
C
      IMPLICIT REAL (A-H,O-Z)

      DIMENSION A(1),KT(1),RHS(1),COST(1),QUAD(1),INPUT(1),
     1    TOL(1),X(1),RC(1),DUAL(1),SLK(1),IOUT(1),WS(1)
      CHARACTER*64  TITLE,PFILE
C
      INTEGER  ROW,COL,INDX,MORE,P,P1,PSQ
      COMMON /QPRCBI/ INPUTS(14),IOUTS(2),ROW,COL,INDX,MORE,P,P1,PSQ,
     1    NCALL,LENREQ,IO1,IO2,IO3
      EQUIVALENCE (INPUTS(1),ML), (INPUTS(2),NL), (INPUTS(3),MO),
     1    (INPUTS(4),NO), (INPUTS(5),MINMAX), (INPUTS(6),LENWS),
     2    (INPUTS(7),MAXIT), (INPUTS(8),KOBJ), (INPUTS(9),JIT),
     3    (INPUTS(10),JDATA), (INPUTS(11),JPIVOT), (INPUTS(12),JSOL),
     4    (INPUTS(13),JOUT), (INPUTS(14),JWIDTH),
     5    (IOUTS(1),IERR), (IOUTS(2),ITCNT)
C
      COMMON /QPRCBR/ TOLS(2)
      EQUIVALENCE (TOLS(1),TZERO), (TOLS(2),TPIV)
C
      DOUBLE PRECISION  PIVOT
      COMMON /QPRCBD/ PIVOT
C
      CHARACTER*64  TITLES, PFILES
      COMMON /QPRCBC/ TITLES, PFILES
C
C     DATA NCALL  / 0 /

      NCALL = 0
C
C     OUTPUT UNITS FOR LINE PRINTER (TERMINAL) AND OUTPUT FILE
      DATA  LUPRNT, LUFILE  / 6, 92 /
C
C
C     INITIALIZATIONS
C
      IO1 = LUPRNT
      IERR = 0
      ITCNT = 0
      TZERO = TOL(1)
      TPIV = TOL(2)
      NCALL = NCALL + 1
      DO 10 I = 1, 14
         INPUTS(I) = INPUT(I)
   10 CONTINUE
      TITLES =
     *'
```

```
C INPUT --- FIXED CONSTANTS VECTOR OF LENGTH 21 CONTAINING ...
C ML      1 ROW DIMENSION OF A IN CALLING PROGRAM.  MINIMUM IS MO.
C NL      2 ROW DIMENSION OF QUAD IN CALLING PROGRAM.  MINIMUM IS NO.
C MO      3 NUMBER OF CONSTRAINTS.
C NO      4 NUMBER OF VARIABLES .
C MINMAX  5 =0 IF OBJECTIVE IS TO BE MINIMIZED,
C           =1 IF OBJECTIVE IS TO BE MAXIMIZED.
C LENWS   6 DIMENSION OF WS IN CALLING PROGRAM.  MINIMUM IS
C           2*(MO+NO)**2 + 12*(MO+NO) + 16 IF ANY EQUALITY CONSTRAINTS
C           ARE PRESENT OR  2*(MO+NO)**2 +  8*(MO+NO) + 6
C           IF ALL CONSTRAINTS ARE INEQUALITIES.
C MAXIT   7 PIVOT LIMIT.
C KOBJ    8 COMPUTE OBJECTIVE AT SOLUTION OPTION.  =0 NO, =1 YES.
C JIT     9 OUTPUT PROBLEM PARAMETERS OPTION.   =0 NO, =1 YES.
C JDATA  10 OUTPUT PROBLEM DATA OPTION.  =0 NO,
C           =1 OUTPUT WITH A AND QUAD MATRICES IN DENSE FORM,
C           =2 OUTPUT WITH A AND QUAD MATRIX IN SPARSE FORM.
C JPIVOT 11 OUTPUT PIVOT INFORMATION.  =0 NO, =1 YES.
C JSOL   12 OUTPUT SOLUTION REPORT OPTION.  =0 NO,
C           =1 OUTPUT BRIEF REPORT,  =2 OUTPUT FULL REPORT.
C JOUT   13 OPTION TO PRINT OR FILE OUTPUT.
C           =0 PRINT ALL OUTPUT,  =1 PRINT PROBLEM PARAMETERS AND FINAL
C           OUTPUT AND FILE OTHER OUTPUT, =2 FILE ALL OUTPUT.
C JWIDTH 14 MAXIMUM WIDTH OF OUTPUT LINES.  A MINIMUM OF 72 AND A
C           MAXIMUM OF 132 WILL BE USED.
C
C TOL   --- TOLERANCE VECTOR OF SIZE 2 CONTAINING...
C TZERO   1 ROUND-OFF OR ZERO TOLERANCE.  IF .LE. 0 RESET TO 1.E-7
C TPIV    2 PIVOT TOLERANCE.  IF .LE. 0 RESET TO 1.E-6
C
C TITLE --- TITLE PRINTED IN OUTPUT.  TYPE CHARACTER.
C           MAY CONTAIN UP TO 64 CHARACTERS.
C           TRUNCATED TO 64 CHARACTERS IF LONGER.
C PFILE --- FILE NAME QUADPR WRITES OUTPUT ONTO IF REQUESTED.
C           TYPE CHARACTER.  MAY CONTAIN UP TO 64 CHARACTERS.
C           IF FILE CANNOT BE OPENED, A FILE WILL BE CREATED
C           AND A MESSAGE PRINTED.  IF THE NAME IS ALL BLANKS,
C           OUTPUT TO BE FILED WILL BE DISCARDED.
C OBJ   --- OBJECTIVE VALUE.
C X     --- NO-VECTOR THAT WILL CONTAIN THE SOLUTION.
C RC    --- NO-VECTOR THAT WILL CONTAIN THE REDUCED COSTS.
C DUAL  --- MO-VECTOR THAT WILL CONTAIN THE DUAL SOLUTION.
C SLK   --- MO-VECTOR THAT WILL CONTAIN THE SLACK VALUES.
C IOUT  --- VECTOR OF SIZE 2, THAT WILL CONTAIN...
C IERR    1 STATUS CODE FROM 1 TO 6.
C           1 - SOLUTION IS OPTIMAL.
C           2 - NO SOLUTION.
C           3 - PIVOT LIMIT REACHED.
C           4 - INVALID QUAD MATRIX.
C           5 - PROBLEM DATA ERROR.
C           6 - ALGORITHM ERROR.
C ITCNT   2 NUMBER OF PIVOTS.
```

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```
      IO2 = LUPRNT
      GO TO 90
C     CANNOT OPEN FILE. MAKE ONE UP.
   60 CONTINUE
      IF (L3 .EQ. 1) GO TO 76
      L3 = 1
      WRITE (IO1,70) NCALL,PFILES(1:L2)
   70 FORMAT ( //// 5X,'QUADPR  CALL',I4
     1          // 1X,'*** UNABLE TO OPEN THE FILE ', A)
      WRITE (PFILES,72) NCALL
C     FORM FILE NAME.
   72 FORMAT ('QDPR',I4.4,'.LIS',52X)
      WRITE (IO1,74) PFILES(1:12)
   74 FORMAT ( / 5X,'OUTPUT WILL BE FILED ON ',A12)
      GO TO 4
C     CANNOT OPEN THIS FILE EITHER.
   76 CONTINUE
      WRITE (IO1,78) LUFILE
   78 FORMAT ( / 5X,'CANNOT OPEN THIS FILE EITHER.  CHECK YOUR FILES '
     1   'FOR THE ABOVE NAME' / 5X,'AND MAKE SURE LOGICAL UNIT',I4,
     2   ' IS CLOSED.' / )
      IERR = 5
      GO TO 200
   80 CONTINUE
      IO2 = LUPRNT
      IO3 = LUPRNT
   90 CONTINUE
C
C     PARTITION WORKSPACE ARRAY.
      L1 = 1 + 2*(PSQ+P)
      L2 = L1 + 2*P1
      L3 = L2 + 2*P1
      L4 = L3 + P1
      LENREQ = L4 + P1 - 1
C
C     CHECK INPUT DATA PARAMETERS FOR CONSISTENCY
      CALL QDRVER (KT)
C
      IF (IERR .EQ. 5) GO TO 200
C     QUIT IF BAD VALUES (IERR = 5)
C
C     OUTPUT PROBLEM PARAMETERS AND PROBLEM DATA IF REQUESTED.
C      IF (JIT .NE. 0) CALL QRPRT1
C      IF (JDATA .NE. 0) CALL QRPRT2 (A,ML,KT,RHS,COST,QUAD,NL)
C
C     OUTPUT HEADER FOR INTERMEDIATE OUTPUT, IF ANY EXPECTED
C      IF (JPIVOT .NE. 0) CALL QRPRT3
C
C     CONSTRUCT INITIAL TABLEAU FOR QUADRATIC PROGRAMMING.
      CALL QDPREP (A,ML,KT,RHS,COST,QUAD,NL,WS,P)
C
C     PERFORM PRINCIPAL PIVOTING TO FINAL TABLEAU.
C      L1 = LEN(TITLE)
      L1 = 30

      TITLES(1:L1) = TITLE(1:L1)
C
C     INTERNAL TABLEAU IS (MO+NO)*(MO+NO+1) IF ALL INEQUALITIES AND
C     (MO+NO+1)*(MO+NO+2) IF ANY EQUALITIES SINCE 1 MORE ROW IS ADDED.
      IF (MO .LE. 0) GO TO 22
      DO 20 I = 1, MO
         IF (KT(I) .EQ. 0) GO TO 24
   20 CONTINUE
   22 CONTINUE
      MORE = 0
      GO TO 26
   24 CONTINUE
      MORE = 1
   26 CONTINUE
      P = MO + NO + MORE
      P1 = P + 1
      PSQ = P**2
C
C     SET OUTPUT UNITS AND OPEN PRINT FILE IF REQUIRED.
      IF (JOUT .NE. 1 .AND. JOUT .NE. 2) GO TO 80
      PFILES =
     *'
C      L1 = LEN(PFILE)
      L1 = 30

      L2 = 0
      L3 = 0
      DO 30 I = 1, L1
         IF (PFILE(I:I) .EQ. ' ') GO TO 30
         L2 = L2 + 1
         PFILES(L2:L2) = PFILE(I:I)
   30 CONTINUE
      IF (L2 .GT. 0) GO TO 40
C     BLANK FILE NAME, DISCARD OUTPUT TO BE FILED.
      JDATA = 0
      JPIVOT = 0
      IF (JOUT .EQ. 2) GO TO 90
      JIT = 0
      JSOL = 0
      GO TO 50
C     OPEN PRINT FILE
   40 CONTINUE
C      OPEN (LUFILE,FILE=PFILES,STATUS='UNKNOWN',ERR=60)
      OPEN (LUFILE,FILE=PFILES)
      IO3 = LUFILE
      IF (JOUT .EQ. 1) GO TO 50
      IO2 = LUFILE
      GO TO 90
   50 CONTINUE
```

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```
      IF (TZERO .LE. 0.0) TZERO = 1.0E-7
      IF (TPIV .LE. 0.0) TPIV = 1.0E-6
      IF (JWIDTH .LT. 72) JWIDTH = 72
      IF (JWIDTH .GT. 132) JWIDTH = 132

      ITITLE = 0

      CHECK KT
      DO 10 I = 1, MO
         IF (IABS(KT(I)) .GT. 1) GO TO 20
   10 CONTINUE
      GO TO 30
   20 CONTINUE
      WRITE (IO1,22) NCALL
   22 FORMAT ( /// 5X,'QUADPR  CALL',I4)
      WRITE (IO1,24) (KT(I),I=1,MO)
   24 FORMAT ( / 1X,'*** ERROR, ILLEGAL VALUES IN KT.  KT CONTAINS'
     1  / (6I12) )
      IERR = 5
      ITITLE = 1

      CHECK INPUT
   30 CONTINUE
      ERROR(1) = (MO .LT. 0 .OR. MO .GT. ML)
      ERROR(2) = (NO .LT. 1 .OR. NO .GT. NL)
      ERROR(3) = (LENWS .LT. LENREQ)
      DO 33 I = 1, 4
         J = ZERONE(I)
         ERROR(I+3) = (INPUTS(J) .NE. 0 .AND. INPUTS(J) .NE. 1)
   33 CONTINUE
      DO 34 I = 1, 3
         J = ZERO12(I)
         ERROR(I+7) = (INPUTS(J) .LT. 0 .OR. INPUTS(J) .GT. 2)
   34 CONTINUE
      DO 35 I = 1, 10
         IF (ERROR(I)) GO TO 38
   35 CONTINUE
      GO TO 50
C
   38 CONTINUE
      IERR = 5
      IF (ITITLE .EQ. 0) WRITE (IO1,22) NCALL
      WRITE (IO1,40) (INPUTS(I),I=1,14)
   40 FORMAT ( / 1X,'*** ERROR, INCONSISTENT DATA IN INPUT.'
     1  '  INPUT CONTAINS' / 5I12 / 5I12 / 4I12 /
     2  / 5X,'THE FOLLOWING ERRORS OCCURRED.' / )
      IF (ERROR(1)) WRITE (IO1,41)
   41 FORMAT (5X,'INPUT(3) NEGATIVE OR EXCEEDS INPUT(1)')
      IF (ERROR(2)) WRITE (IO1,42)
   42 FORMAT (5X,'INPUT(4) NON-POISTIVE OR EXCEEDS INPUT(2)')
      IF (ERROR(3)) WRITE (IO1,43) LENREQ
   43 FORMAT (5X,'INPUT(6) TOO SMALL.  FOR THIS PROBLEM,',
```

```
      CALL QDCOMP (WS,WS(L1),WS(L2),WS(L3),WS(L4))
C
C     GET SOLUTION AND OBJECTIVE VALUE IF REQUESTED.
      CALL QDSOLN (KT,COST,QUAD,NL,WS,P,WS(L4),X,RC,DUAL,SLK,
     1   WS(L1),OBJ)
C
C     OUTPUT SOLUTION REPORT IF REQUESTED.
C      IF (JSOL .NE. 0) CALL QRPRT6 (X,RC,DUAL,SLK,OBJ)
C
C     SET EXIT VALUES, IOUT.
  200 CONTINUE
      IOUT(1) = IERR
      IOUT(2) = ITCNT
C
C     CLOSE PRINT FILE IF REQUIRED.
      IF (JOUT .GT. 0) CLOSE (LUFILE,STATUS='KEEP')
C
      RETURN
C
      END
*****************************************************************

      SUBROUTINE QDRVER (KT)
C
C     CHECK INPUT DATA FOR QUADPR
C
      IMPLICIT REAL (A-H,O-Z)
      DIMENSION KT(1)
C
      INTEGER  ROW,COL,INDX,P,P1,PSQ
      COMMON /QPRC01/ INPUTS(14),IOUTS(2),ROW,COL,INDX,MORE,P,P1,PSQ,
     1   NCALL,LENREQ,IO1,IO2,IO3
      EQUIVALENCE (INPUTS(1),ML), (INPUTS(2),NL), (INPUTS(3),MO),
     1   (INPUTS(4),NO), (INPUTS(5),MINMAX), (INPUTS(6),LENWS),
     2   (INPUTS(7),MAXIT), (INPUTS(8),KOBJ), (INPUTS(9),JIT),
     3   (INPUTS(10),JDATA), (INPUTS(11),JPIVOT), (INPUTS(12),JSOL),
     4   (INPUTS(13),JOUT), (INPUTS(14),JWIDTH),
     5   (IOUTS(1),IERR), (IOUTS(2),ITCNT)
C
      COMMON /QPRCBR/ TOLS(2)
      EQUIVALENCE (TOLS(1),TZERO), (TOLS(2),TPIV)
C
      INTEGER ZERONE(4),ZERO12(3)
      LOGICAL ERROR(10)
      DATA ZERONE  / 5,8,9,11 /
      DATA ZERO12  / 10,12,13 /
C
C
      ITITLE = 0
C
C     DEFAULT VALUES
      IF (MAXIT .LE. 0) MAXIT = 1000
```

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```
     1    ' MUST BE AT LEAST',I8)
      DO 45 I = 1, 4
         J = ZERONE(I)
         IF (ERROR(I+3)) WRITE (IO1,46) J
45    CONTINUE
46    FORMAT (5X,'INPUT(',I2,') NOT 0 OR 1')
      DO 47 I = 1, 3
         J = ZERO12(I)
         IF (ERROR(I+7)) WRITE (IO1,48) J
47    CONTINUE
48    FORMAT (5X,'INPUT(',I2,') NOT 0, 1, OR 2')
C
50    CONTINUE
      RETURN
      END
**********************************************************************

      SUBROUTINE QDPREP (A,LDA,KT,RHS,COST,QUAD,LDQ,B,LDB)
C
C     CONSTRUCT THE INITIAL TABLEAU FOR QUADRATIC PROGRAMMING.
C     IT HAS THE FORM
C              .....................................
C              .              (T)   .    (T)  .      .
C              .  QUAD'+QUAD        .  -A'    . COST'.
C              .     [1]            .  [2]    . [3]  .
C     B    =   .....................................
C              .     A'             .   0     . -RHS'.
C              .     [4]            .  [5]    . [6]  .
C              .....................................
C
C     WHERE A',RHS',COST',QUAD' ARE OBTAINED FROM A,RHS,COST,QUAD BY
C     CONVERTING THE PROBLEM TO MINIMIZATION WITH ALL .GE. CONSTRAINTS.
C
      IMPLICIT REAL (A-H,O-Z)

      DOUBLE PRECISION  B
      DIMENSION  A(LDA,1),KT(1),RHS(1),COST(1),QUAD(LDQ,1),B(LDB,1)
C
      INTEGER  ROW,COL,INDX,MORE,P,P1,PSQ
      COMMON /QPRCBI/ INPUTS(14),IOUTS(2),ROW,COL,INDX,MORE,P,P1,PSQ,
     1   NCALL,LENREQ,IO1,IO2,IO3
      EQUIVALENCE (INPUTS(1),ML), (INPUTS(2),NL), (INPUTS(3),MO),
     1   (INPUTS(4),NO), (INPUTS(5),MINMAX), (INPUTS(6),LENWS),
     2   (INPUTS(7),MAXIT), (INPUTS(8),KOBJ), (INPUTS(9),JIT),
     3   (INPUTS(10),JDATA), (INPUTS(11),JPIVOT), (INPUTS(12),JSOL),
     4   (INPUTS(13),JOUT), (INPUTS(14),JWIDTH),
     5   (IOUTS(1),IERR), (IOUTS(2),ITCNT)
C
C
C     FILL LOWER TRIANGLE OF [1] AND [3].
      N1 = NO - 1
      IF (MINMAX .EQ. 1) GO TO 40
C     MIN. PROBLEM
      B(1,1) = 2.0*QUAD(1,1)
      B(1,P1) = COST(1)
      IF (NO .EQ. 1) GO TO 110
      DO 10 K = 2, NO
         B(K,K) = 2.0*QUAD(K,K)
         B(K,P1) = COST(K)
10    CONTINUE
      DO 30 L = 1, N1
         L1 = L + 1
         DO 20 K = L1, NO
            B(K,L) = QUAB(K,L) + QUAD(L,K)
20       CONTINUE
30    CONTINUE
      GO TO 80
C     MAX. PROBLEM
40    CONTINUE
      B(1,1) = - 2.0*QUAD(1,1)
      B(1,P1) = - COST(1)
      IF (NO .EQ. 1) GO TO 110
      DO 50 K = 2, NO
         B(K,K) = - 2.0*QUAD(K,K)
         B(K,P1) = - COST(K)
50    CONTINUE
      DO 70 L = 1, N1
         L1 = L + 1
         DO 60 K = L1, NO
            B(K,L) = - QUAD(K,L) - QUAD(L,K)
60       CONTINUE
70    CONTINUE
C
C     FILL UPPER TRAINGLE OF [1].
80    CONTINUE
      DO 100 L = 2, NO
         L1 = L - 1
         DO 90 K = 1, L1
            B(K,L) = B(L,K)
90       CONTINUE
100   CONTINUE
C
C     CHECK FOR CASE OF NO CONSTRAINTS.
110   CONTINUE
      IF (MO .EQ. 0) GO TO 240
C
C     FILL [5].
      N1 = NO + 1
      DO 130 L = N1, P
         DO 120 K = N1, P
            B(K,L) = 0.0
120      CONTINUE
130   CONTINUE
C
```

```
C     COMPUTE THE FINAL TABLEAU FOR QUADRATIC PROGRAMMING GIVEN
C     THE INITIAL TABLEAU USING THE METHOD OF PRINCIPAL PIVOTING.
C
      IMPLICIT REAL (A-H,O-Z)

      DOUBLE PRECISION  B,TEMP,U
      INTEGER  JZ,JW
      DIMENSION  B(1),TEMP(1),U(1),JZ(1),JW(1)
C
      INTEGER  ROW,COL,INDX,P,P1,PSQ
      COMMON /QPRCBI/ INPUTS(14),IOUTS(2),ROW,COL,INDX,MORE,P,P1,PSQ,
     1    NCALL,LENREQ,IO1,IO2,IO3
      EQUIVALENCE (INPUTS(1),ML), (INPUTS(2),NL), (INPUTS(3),MO),
     1    (INPUTS(4),NO), (INPUTS(5),MINMAX), (INPUTS(6),LENWS),
     2    (INPUTS(7),MAXIT), (INPUTS(8),KOBJ), (INPUTS(9),JIT),
     3    (INPUTS(10),JDATA), (INPUTS(11),JPIVOT), (INPUTS(12),JSOL),
     4    (INPUTS(13),JOUT), (INPUTS(14),JWIDTH),
     5    (IOUTS(1),IERR), (IOUTS(2),ITCNT)
C
      COMMON /QPRCBR/ TOLS(2)
      EQUIVALENCE (TOLS(1),TZERO), (TOLS(2),TPIV)
C
      DOUBLE PRECISION  PIVOT
      COMMON /QPRCBD/ PIVOT
C
      DOUBLE PRECISION  Z,BS,BST
      CHARACTER*48  MSG(4)
C
      DATA MSG / 'ALGORITHM ERROR, INDEX VALUE NON-DECREASING.     ',
     2           'NO SOLUTION, INVALID QUADRATIC COSTS MATRIX.     ',
     3           'NO SOLUTION, INFEASIBLE OR UNBOUNDED PROBLEM.    ',
     4           'ERROR, ITERATION LIMIT REACHED.                  '/
C
C
C*****INITIALIZATIONS
      ITCNT = 0
      JFLAG = 0
      INDX = P1
C*****BASIC VARIABLES GET NEGATIVE VALUES.
C*****NONBASIC VARIABLES(JZ) GET POSITIVE VALUES.
      DO 30 I = 1, P
         JW(I) = -I
         JZ(I) = I
   30 CONTINUE
   40 ITEMP = 0
C*****CHECK FOR NONDECREASING INDEX (ALLOW UP TO 5 EQUAL INDEXES FOR
C*****TOLERANCE PURPOSES).
      IJ = PSQ
      DO 50 I = 1, P
         IJ = IJ + 1
         IF (B(IJ) .LT. (-TZERO)) ITEMP = ITEMP + 1
   50 CONTINUE
C     IF THERE ARE R .EQ. CONSTRAINTS, EXPRESS AS R+1 .GE. CONSTRAINTS,
C     THE LATTER BEING MINUS THE SUM OF THE OTHERS.
      IF (MORE .EQ. 0) GO TO 150
      DO 140 L = 1, NO
         B(P,L) = 0.0
  140 CONTINUE
      B(P,P1) = 0.0
C
C     FILL [4] AND [6].
  150 CONTINUE
      DO 210 I = 1, MO
         K = NO + I
         IF (KT(I) .LT. 0) GO TO 170
         IF (KT(I) .GT. 0) GO TO 190
C        .EQ. CONSTRAINT
         DO 160 L = 1, NO
            B(K,L) = A(I,L)
            B(P,L) = B(P,L) - B(K,L)
  160    CONTINUE
         B(K,P1) = - RHS(I)
         B(P,P1) = B(P,P1) - B(K,P1)
         GO TO 210
C        .GE. CONSTRAINT
  170    CONTINUE
         DO 180 L = 1, NO
            B(K,L) = A(I,L)
  180    CONTINUE
         B(K,P1) = - RHS(I)
         GO TO 210
C        .LE. CONSTRAINT
  190    CONTINUE
         DO 200 L = 1, NO
            B(K,L) = - A(I,L)
  200    CONTINUE
         B(K,P1) = RHS(I)
  210 CONTINUE
C
C     FILL [2].
      DO 230 L = 1, NO
         DO 220 K = N1, P
            B(L,K) = - B(K,L)
  220    CONTINUE
  230 CONTINUE
C
C     FINISHED
  240 CONTINUE
      RETURN
      END
*****************************************************************************

      SUBROUTINE QDCOMP (B,TEMP,U,JZ,JW)
C
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```
      IF (B(KJ) .LT. (-TZERO) .OR. BST .GE. (-TPIV)) GO TO 140
      IF (DABS(B(KJ)) .LT. TZERO .AND. B(IJ) .LT. (-TZERO)) GO TO 120

      IF (B(KJ)) 130, 140, 130
  120 ROW = J
      GO TO 150
  130 BST = -BST / B(KJ)
      IF (BST .LE. BS) GO TO 140
      BS = BST
      ROW = J
  140 CONTINUE
      IF (ROW .EQ. 0) GO TO 210
C*****NONPRINCIPAL PIVOT ON B(S,R).
C*****AT THIS POINT THE BLOCKING VARIABLE IS B(NS,I).
  150 III = -JW(ROW)
      NFLAG = 1
      GO TO 500
  160 CONTINUE
      IF (ITCNT .GE. MAXIT) GO TO 440
      ITCNT = ITCNT + 1
C*****ATTEMPT TO PROGRESSIVELY RELAX THE CONVERGENCE PARAMETER

C     TPIV = TPIV + TOLS(2)/50.
C*****INDICATE THE NUMBER OF ITERATIONS
      WRITE(*,101)'OPTIMIZATION ITERATION      ',ITCNT
  101 FORMAT('+',A50,I5)

      JFLAG = 0
C*****PUT TOLERANCE ON B(I,P1) AFTER A NONPRINCIPAL PIVOT.
      IJ = PSQ + I
      IF (B(IJ) .LT. (-TZERO)) GO TO 170
      GO TO 10
C*****THE NEW DRIVING VARIABLE IS THE COMPLEMENT OF THE OLD BLOCKING
C*****VARIABLE
  170 DO 180 JJ = 1, P
          IF (JZ(JJ) .EQ. III) GO TO 190
  180 CONTINUE
C*****NO COMPLEMENT VARIABLE (NOT ALLOWED IF POS. SEMIDEF.)
      GO TO 410
  190 COL = JJ
C*****THE DISTINGUISHED VARIABLE IS STILL THE I-TH ROW.
      IJ = P*(COL-1) + I
      IF (B(IJ) .GT. TPIV) GO TO 200
      II = COL
      GO TO 60
  200 KJ = PSQ + I
      Z = -B(KJ) / B(IJ)
      GO TO 110
C*****PRINCIPAL PIVOT ON B(I,I).
  210 LL = ROW
      ROW = I
      NFLAG = 2
      IF (ITEMP .NE. INDX) ICT = 0
      IF (ITEMP .EQ. INDX) ICT = ICT + 1
      IF (ITEMP .GT. INDX .OR. ICT .EQ. 5) GO TO 400
C*****IF THE INDEX IS ZERO YOU ARE DONE.
      IF (ITEMP .EQ. 0) GO TO 300
      INDX = ITEMP
      IJ = PSQ
      DO 60 I = 1, P
         IJ = IJ + 1
         IF (B(IJ) .LT. (-TZERO)) GO TO 70
   60 CONTINUE
   70 IJ = P*(I-1) + I
C*****CHECK FOR NEGATIVE DIAGONAL ELEMENT (NOT ALLOWED IF POS. SEMIDEF.)
      IF (B(IJ) .LT. (-TPIV)) GO TO 410
      IF (B(IJ) .GT. TPIV) GO TO 100
C*****IF POTENTIAL PIVOT ELEMENT IS NEAR ZERO, USE CODE BELOW
C*****TO DETERMINE THE BLOCKING VARIABLE.
      II = I
   80 ROW = 0
      TMMP = 1000000.
      IJ = PSQ
      KJ = P*(II-1)
      DO 90 J = 1, P
         IJ = IJ + 1
         KJ = KJ + 1
         IF (B(IJ) .LT. (-TZERO)) GO TO 90
C********IF ALL COL. ELEMENTS ARE NONNEGATIVE, THEN THE DRIVING VARIABLE
C********IS UNBLOCKED AND THERE IS NO SOLUTION.
         IF (B(KJ) .GE. (-TPIV)) GO TO 90
         Z = -B(IJ) / B(KJ)
         IF (Z .GE. TMMP) GO TO 90
         TMMP = Z
         ROW = J
   90 CONTINUE
      IF (ROW. EQ. 0) GO TO 420
      COL = II
      GO TO 150
C*****COMPUTE Z = -Q(R)/B(R,R), THE INCREASE IN THE DRIVING VARIABLE.
  100 IJ = PSQ + I
      KJ = P*(I-1) + I
      Z = -B(IJ) / B(KJ)
      COL = I
  110 BST = 0.
      ROW = 0
C*****FIND THE NEW BLOCKING VARIABLE, BASED ON WHICH BASIC VARIABLE IS
C*****MOST AFFECTED BY THE CHANGE IN THE DRIVING VARIABLE.
      IJ = (COL-1)*P
      KJ = PSQ
      DO 140 J = 1, P
         IJ = IJ + 1
         KJ = KJ + 1
         BST = B(IJ)*Z + B(KJ)
```

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```
   IF (JPIVOT .EQ. 1) CALL QRPRTS
   IF (IND( .GT. 1) GO TO 40

 **NORMAL TERMINATION
10 IERR = 1
   GO TO 600

 ***ERROR TERMINATION
30 K = 1
   IERR = 6
   GO TO 460
10 K = 2
   IERR = 4
   GO TO 460
120 K = 3
   IERR = 2
   GO TO 460
440 K = 4
   IERR = 3
460 WRITE (101,470) MSG(K),ITCNT
   IF (JOUT .NE. 0) WRITE (103,470) MSG(K),ITCNT
470 FORMAT( / 1X,A48,I6,' PIVOTS PERFORMED.' / )
   GO TO 500

 *****PIVOT CODE.
 *****QUADPP USES A NORMAL JORDAN PIVOT.
 *****HOWEVER, WE CAN SAVE MEMORY BY USING THE ELEMENTARY MATRIX.
 *****STORE PIVOT ELEMENT
 500 CONTINUE
     KC = P*(COL-1)
     KJ = KC + ROW
     PIVOT = B(KJ)
     Z = 1.0D0 / PIVOT
C*****STORE ELEMENTARY-VECTOR AND U-VECTOR.
     IJ = ROW
     ISAVE = I
     DO 510 I = 1, P1
        U(I) = B(IJ)
        IJ = IJ + P
 510 CONTINUE
     IJ = KC
     DO 520 I = 1, P
     IJ = IJ + 1
        TEMP(I) = -B(IJ) * Z
 520 CONTINUE
     TEMP(ROW) = -Z - 1.0D0
C*****COMPLETE ALL COLUMNS EXCEPT PIVOT COLUMN.
     IJ = 0
     DO 540 J = 1, P1
        IF (J .NE. COL) GO TO 530
        IJ = IJ + P
        GO TO 500
 220 CONTINUE
     IF (JFLAG .EQ. 1) GO TO 290
     JFLAG = 1
C*****MUST REARRANGE THE ROWS AND COLUMNS FOR COMPLEMENTARITY
C*****EXCHANGE ROWS
 230 LLL = 0
     DO 250 I = 1, P
     K = IABS(JW(I))
     IF (K .EQ. I) GO TO 250
     IJ = K
     KJ = I
     DO 240 J = 1, P1
        Z = B(IJ)
        B(IJ) = B(KJ)
        B(KJ) = Z
        IJ = IJ + P
        KJ = KJ + P
 240 CONTINUE
     II = JW(I)
     JW(I) = JW(K)
     JW(K) = II
     LLL = LLL + 1
 250 CONTINUE
     IF (LLL .GE. 2) GO TO 230
C*****EXCHANGE COLUMNS
 260 LLL = 0
     DO 280 J = 1, P
        K = IABS(JZ(J))
        IF (K .EQ. J) GO TO 280
        IJ = P*(K-1)
        KJ = P*(J-1)
        DO 270 I = 1, P
           IJ = IJ + 1
           KJ = KJ + 1
           Z = B(IJ)
           B(IJ) = B(KJ)
           B(KJ) = Z
 270    CONTINUE
        II = JZ(J)
        JZ(J) = JZ(K)
        JZ(K) = II
        LLL = LLL + 1
 280 CONTINUE
     IF (LLL .GE. 2) GO TO 260
 290 ROW = LL
     ITCNT = ITCNT + 1
C*****ATTEMPT TO PROGRESSIVELY RELAX THE CONVERGENCE PARAMETER

C       TPIV = TPIV + TOLS(2)/50.
C*****INDICATE THE NUMBER OF ITERATIONS
      WRITE(*,101)'OPTIMIZATION ITERATION       ',ITCNT
```

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```
      IF (JPIVOT .EQ. 1) CALL QRPRT5
      IF (INDX .GT. 1) GO TO 40

C*****NORMAL TERMINATION
   30 IERR = 1
      GO TO 600

C*****ERROR TERMINATION
   90 K = 1
      IERR = 6
      GO TO 460
  410 K = 2
      IERR = 4
      GO TO 460
  420 K = 3
      IERR = 2
      GO TO 460
  440 K = 4
      IERR = 3
  460 WRITE (IO1,470) MSG(K),ITCNT
      IF (JOUT .NE. 0) WRITE (IO3,470) MSG(K),ITCNT
  470 FORMAT( / 1X,A48,I6,' PIVOTS PERFORMED.' / )
      GO TO 600

C*****PIVOT CODE.
C*****QUADPP USES A NORMAL JORDAN PIVOT.
C*****HOWEVER, WE CAN SAVE MEMORY BY USING THE ELEMENTARY MATRIX.
C*****STORE PIVOT ELEMENT
  500 CONTINUE
      KC = P*(COL-1)
      KJ = KC + ROW
      PIVOT = B(KJ)
      Z = 1.0D0 / PIVOT
C*****STORE ELEMENTARY-VECTOR AND U-VECTOR.
      IJ = ROW
      ISAVE = I
      DO 510 I = 1, P1
         U(I) = B(IJ)
         IJ = IJ + P
  510 CONTINUE
      IJ = KC
      DO 520 I = 1, P
      IJ = IJ + 1
         TEMP(I) = -B(IJ) * Z
  520 CONTINUE
      TEMP(ROW) = -Z - 1.0D0
C*****COMPUTE ALL COLUMNS EXCEPT PIVOT COLUMN.
      IJ = 0
      DO 550 J = 1, P1
         IF (J .NE. COL) GO TO 530
         IJ = IJ + P
      GO TO 500
  220 CONTINUE
      IF (JFLAG .EQ. 1) GO TO 290
      JFLAG = 1
C*****MUST REARRANGE THE ROWS AND COLUMNS FOR COMPLEMENTARITY
C*****EXCHANGE ROWS
  230 LLL = 0
      DO 250 I = 1, P
      K = IABS(JW(I))
      IF (K .EQ. I) GO TO 250
      IJ = K
      KJ = I
      DO 240 J = 1, P1
         Z = B(IJ)
         B(IJ) = B(KJ)
         B(KJ) = Z
         IJ = IJ + P
         KJ = KJ + P
  240 CONTINUE
      II = JW(I)
      JW(I) = JW(K)
      JW(K) = II
      LLL = LLL + 1
  250 CONTINUE
      IF (LLL .GE. 2) GO TO 230
C*****EXCHANGE COLUMNS
  260 LLL = 0
      DO 280 J = 1, P
         K = IABS(JZ(J))
         IF (K .EQ. J) GO TO 280
         IJ = P*(K-1)
         KJ = P*(J-1)
         DO 270 I = 1, P
            IJ = IJ + 1
            KJ = KJ + 1
            Z = B(IJ)
            B(IJ) = B(KJ)
            B(KJ) = Z
  270    CONTINUE
         II = JZ(J)
         JZ(J) = JZ(K)
         JZ(K) = II
         LLL = LLL + 1
  280 CONTINUE
      IF (LLL .GE. 2) GO TO 260
  290 ROW = LL
      ITCNT = ITCNT + 1
C*****ATTEMPT TO PROGRESSIVELY RELAX THE CONVERGENCE PARAMETER

C     TPIV = TPIV + TOLS(2)/50.
C*****INDICATE THE NUMBER OF ITERATIONS
      WRITE(*,101)'OPTIMIZATION ITERATION      ',ITCNT
```

```
      DOUBLE PRECISION DART, BB

      GET X, RC, DUAL, SLK
   00 CONTINUE
      KART = MO + 1
      DO 110 J = 1, NO
         X(J) = 0.0
         RC(J) = 0.0
   110 CONTINUE
      DO 120 I = 1, MO
         DUAL(I) = 0.0
         SLK(I) = 0.0
   120 CONTINUE
      DART = 0.0D0
      DO 170 I = 1, P
         BB = B(I,P1)
         IF (DABS(BB) .LT. TZERO) BB = 0.0D0
         J = JW(I)
         IF (J .LT. 0) GO TO 150
         IF (J .GT. NO) GO TO 130
         X(J) = BB
         GO TO 170
   130   CONTINUE
         J = J - NO
         IF (K .EQ. KART) GO TO 140
         DUAL(K) = BB
         GO TO 170
   140   CONTINUE
         DART = BB
         GO TO 170
   150   CONTINUE
         J = -J
         IF (J .GT. NO) GO TO 160
         RC(J) = BB
         GO TO 170
   160   CONTINUE
         K = J - NO
         IF (K .EQ. KART) GO TO 170
         SLK(K) = BB
   170 CONTINUE
C
C     ADJUST DUALS IF ANY EQUALITIES
      IF (MORE .EQ. 0) GO TO 200
      DO 190 I = 1, MO
         IF (KT(I) .NE. 0) GO TO 190
         IF (MINMAX .EQ. 1) GO TO 180
         DUAL(I) = DUAL(I) - DART
         GO TO 190
   180   CONTINUE
         DUAL(I) = DART - DUAL(I)
         GO TO 550
   530   DO 540 I = 1, P
            IJ = IJ + 1
            B(IJ) = B(IJ) + U(J)*TEMP(I)
   540   CONTINUE
   550 CONTINUE
C*****COMPUTE PIVOT COLUMN.
      IJ = KC
      DO 560 I = 1, P
         IJ = IJ + 1
         B(IJ) = -TEMP(I)
   560 CONTINUE
C*****COMPUTE NEW PIVOT ELEMENT.
      B(KJ) = Z
C*****KEEP TRACK OF BASIC AND NONBASIC VARIABLES
      K = JW(ROW)
      JW(ROW) = JZ(COL)
      JZ(COL) = K
C      IF (JPIVOT .EQ. 1) CALL QRPRT4
      I = ISAVE
      GO TO (160, 220), NFLAG
C
C*****FINISHED
   600 RETURN
      END
*************************************************************************

      SUBROUTINE QDSOLN (KT,COST,QUAD,LDQ,B,LDB,JW,X,RC,DUAL,SLK,
     1   TEMP,OBJ)
C
C     RETURN SOLUTION TO QUADRATIC PROGRAMMING PROBLEM FROM FINAL
C     TABLEAU AND COMPUTE OBJECTIVE VALUE IF REQUESTED.
C     CONVERTING THE PROBLEM TO MINIMIZATION WITH ALL .GE. CONSTRAINTS.
C
      IMPLICIT REAL (A-H,O-Z)

      DOUBLE PRECISION  B,TEMP
      DIMENSION  KT(1),COST(1),QUAD(LDQ,1),B(LDB,1),JW(1),X(1),RC(1),
     1   DUAL(1),SLK(1),TEMP(1)
C
      INTEGER  ROW,COL,INDX,MORE,P,P1,PSQ
      COMMON /QPRCBI/ INPUTS(14),IOUTS(2),ROW,COL,INDX,MORE,P,P1,PSQ,
     1   NCALL,LENREQ,IO1,IO2,IO3
      EQUIVALENCE (INPUTS(1),ML), (INPUTS(2),NL), (INPUTS(3),MO),
     1   (INPUTS(4),NO), (INPUTS(5),MINMAX), (INPUTS(6),LENWS),
     2   (INPUTS(7),MAXIT), (INPUTS(8),KOBJ), (INPUTS(9),JIT),
     3   (INPUTS(10),JDATA), (INPUTS(11),JPIVOT), (INPUTS(12),JSOL),
     4   (INPUTS(13),JOUT), (INPUTS(14),JWIDTH),
     5   (IOUTS(1),IERR), (IOUTS(2),ITCNT)
C
      COMMON /QPRCBR/ TOLS(2)
      EQUIVALENCE (TOLS(1),TZERO), (TOLS(2),TPIV)
```

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```
      DO 10 I = 1,NUM
      DO 10 J = 1,NUM
      IF(I.EQ.J) THEN
      QC(I,J) = -1.0

        IF(ITURN.EQ.1) THEN

C***IF THE OLD WEIGHT EQUALS ZERO
          IF (OLDWT(I) .LT. 0.001) THEN
            QC(I,J) = -1.0
C***IF THE OLD WEIGHT EQUALS THE UPPER BOUND
          ELSE IF (OLDWT(I) .GT. 0.95*BDU(I)) THEN
            QC(I,J) = -1.0
C***IF X(I) IS LESS THAN THE OLD WEIGHT
          ELSE IF (X(I) .LE. OLDWT(I)) THEN
            QC(I,J) = -1.0
C***IF X(I) IS GREATER THAN THE OLD WEIGHT
          ELSE IF (X(I) .GT. OLDWT(I)) THEN
            IF (X(I) .GT. 0.95*BDU(I)) THEN
              QC(I,J) = -1.0
            ELSE
              QC(I,J) = 1.0
            END IF
          END IF

        END IF

      ELSE
        QC(I,J) = 0.0
      END IF
20    CONTINUE

      DO 30 I = 1,NUM+ID
        IF(I.LE.NUM) THEN
          QRHS(I) = -BDU(I)

        IF(ITURN.EQ.1) THEN

C***IF THE OLD WEIGHT EQUALS ZERO
          IF (OLDWT(I) .LT. 0.001) THEN
            QRHS(I) = -BDU(I)
C***IF THE OLD WEIGHT EQUALS THE UPEPR BOUND
          ELSE IF (OLDWT(I) .GT. 0.95*BDU(I)) THEN
            QRHS(I) = -BDU(I)
C***IF X(I) IS LESS THAN THE OLD WEIGHT
          ELSE IF (X(I) .LE. OLDWT(I)) THEN
            QRHS(I) = -OLDWT(I)
C***IF X(I) IS GREATER THAN THE OLD WEIGHT
          ELSE IF (X(I) .GT. OLDWT(I)) THEN
            IF (X(I) .GT. 0.95*BDU(I)) THEN
              QRHS(I) = -BDU(I)
            ELSE
```

```
  190 CONTINUE
C
C     COMPUTE OBJECTIVE VALUE ONLY IF REQUESTED.
  200 CONTINUE
      IF (KOBJ .EQ. 0) GO TO 250
      OBJ = 0.
      DO 220 I = 1, NO
         TEMP(I) = 0.0D0
         DO 210 J = 1, NO
            TEMP(I) = TEMP(I) + X(J)*QUAD(I,J)
  210    CONTINUE
  220 CONTINUE
      DO 230 J = 1, NO
         OBJ = OBJ + TEMP(J)*X(J)
  230 CONTINUE
      DO 240 J = 1, NO
         OBJ = OBJ + COST(J)*X(J)
  240 CONTINUE
C
C     FINISHED
  250 CONTINUE
      RETURN
      END
C*********************************************************************
C  UPDATED December 6, 1988
**********************************************************************
      SUBROUTINE QSET(NUM,MAXWS,ITURN)
**********************************************************************
      INCLUDE 'COMSUC.F'

      REAL O(4),S(4),XMAX(ND)
      INTEGER KK(4)

      REAL QC(NDID,ND),QRHS(NDID),QTOL(2),QRC(ND),
     &                 QDUAL(NDID),QSLK(NDID),QWS(ISIZEQ),QB(ND)

      INTEGER QKT(NDID),INPUT(14),QIOUT(2),NUM,MAXWS
      CHARACTER*30 PFILE

C **** IF THE OPTIMAL PORTFOLIO IS WITHIN TURNOVER LIMIT, RETURN ****
      IF (ITURN .EQ. 1) THEN
      COST = 0.0
      DO 5 I = 1,NUM
         COST = COST + ABS(X(I)-OLDWT(I))
5     CONTINUE
      TURN = TURN/2.0 * COST
      END IF

      DO 10 I = 1,ID
      DO 10 J = 1,NUM
10       QC(I+NUM,J)=C(J,I)
```

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```
            IF (X(I) .GT. 0.95*BDU(I)) THEN
               QC(NUM+6,I) = -1.0
               QRHS(NUM+6) = QRHS(NUM+6) - OLDWT(I)
            ELSE
               QC(NUM+6,I) = -1.0
               QRHS(NUM+6) = QRHS(NUM+6) - OLDWT(I)
            END IF
         END IF
         END IF

40    CONTINUE

      WRITE(*,150)ITURN+1
150   FORMAT(1X,T55,I4)

CCCCCCCCCCCCCCCCCCCCCC    SECOND PART  CCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

C*** CHECK IS THE PERCENTAGE CHANGE IN OBJ FUNCTION
      CHECK = 5.0
      IF(ITURN .EQ. 0 .AND. TURN .GT. 0.0) CHECK = CHECK*2.5
      CHECK = CHECK /100.

      SCALE = 10.0
      SCALAST = -10.
      ICOUNT = 0
      DELTA = 1.5
      KK(1) = 1
      KK(2) = 2
      KK(3) = 3
      IBOUND = 0
      OBJMAX = -1000000.
      OBJSTAR = OBJMAX


C ***** LOOP FOR  CORRELATION **********************************

90    CONTINUE

      CHANG2 = (SCALE - SCALMAX)/ABS(SCALMAX)
      ICOUNT = ICOUNT + 1

      DO 45 I = 1,NUM
         B(I) = -B(I)*SCALE
45    CONTINUE
C ********    INITIALIZE  ARRAYS    ***********
      DO 46 I = 1, NUM+ID
         DUAL(I) = 0.0
         SLK(I) = 0.0
46    CONTINUE
      DO 47 I = 1, NUM
         X(I) = 0.0
         RC(I) = 0.0
```

```
            QRHS(I) = OLDWT(I)
         END IF

      END IF
      END IF

      ELSE
         QRHS(I) = D(I-NUM)
      END IF
      QKT(I) = -1
30    CONTINUE

      INPUT(1) = ND+ID
      INPUT(2) = ND
      INPUT(3) = NUM+ID
      INPUT(4) = NUM
      INPUT(5) = 0
      INPUT(6) = MAXWS
      INPUT(7) = 0
      INPUT(8) = 0
      INPUT(9) = 0
      INPUT(10) = 0
      INPUT(11) = 0
      INPUT(12) = 0
      INPUT(13) = 0
      INPUT(14) = 0

      QTOL(1) = 0.0
C E-6
      QTOL(2) = 0.000001
C E-4      QTOL(2) = 0.0001

      PFILE = 'TEMP.Q'

      IF (ITURN.EQ.1) QRHS(NUM+6) = -TURN
      DO 40 I = 1,NUM
         IF(ITURN.EQ.1) THEN

C***IF THE OLD WEIGHT EQUALS ZERO
         IF (OLDWT(I) .LT. 0.001) THEN
            QC(NUM+6,I) = -1.0
            QRHS(NUM+6) = QRHS(NUM+6) - OLDWT(I)
C***IF THE OLD WEIGHT EQUALS THE UPEPR BOUND
         ELSE IF (OLDWT(I) .GT. 0.95*BDU(I)) THEN
            QC(NUM+6,I) = 1.0
            QRHS(NUM+6) = QRHS(NUM+6) + OLDWT(I)
C***IF X(I) IS LESS THAN THE OLD WEIGHT
         ELSE IF (X(I) .LE. OLDWT(I)) THEN
            QC(NUM+6,I) = 1.0
            QRHS(NUM+6) = QRHS(NUM+6) + OLDWT(I)
C***IF X(I) IS GREATER THAN THE OLD WEIGHT
         ELSE IF (X(I) .GT. OLDWT(I)) THEN
```

```
         XMAX(I) = X(I)
80    CONTINUE
      ICOUNT = ICOUNT + 1
      GO TO 49

      RETURN
      END
C*********************************************************************
C UPDATED:December 6, 1988
C ******** SUBROUTINE SUCCESS ****************************
      SUBROUTINE SUCCESS(NUM)
      INCLUDE 'COMSUC.F'

C ******** CALCULATE VARIANCE AND COVARIANCE ***************
      XVAR = 0.0
      COVAR = 0.0
      BB = BULLET
      DO 10 I = 1, NUM
         F(I) = 0.0
         COVAR = COVAR + B(I)*X(I)/BB
         DO 20 J = 1, NUM
            XVAR = XVAR + X(I) * X(J) * A(I,J)
            F(I) = F(I) + 2.0 * X(J) * A(I,J)
20       CONTINUE
10    CONTINUE

C ******** CALCULATE GRADIENT G( ) AND HESSIAN H( , ) ******
      VAR1 = 1./SQRT(XVAR)
      VAR3 = VAR1*1./XVAR
      VAR5 = VAR2*1./XVAR

      DO 30 I = 1, NUM
         G(I) = B(I)/BB*VAR1 - 0.5*COVAR*VAR3*F(I)
         DO 40 J = 1,NUM
            H(I,J) = -0.5*B(I)/BB*VAR3*F(J) - 0.5*B(J)/BB*VAR3*F(I)
     &             -0.5*COVAR*(-1.5*VAR5*F(I)*F(J) + VAR3*2.0*A(I,J))
C ******** ADD -X( )-TRANSPOSE * H( , ) TO THE GRADIENT ****
            G(I) = G(I) - X(J)* H(I,J)
C ******** TAKE 1/2 OF THE HESSIAN TO SEND TO OPTIMIZER ****

            H(I,J) = 0.5*H(I,J)
40       CONTINUE
C ******** SET F( ) EQUAL TO X( ) TO SAVE THE OLD X( ) *****
30    CONTINUE

      DO 50 I = 1,NUM
         F(I) = X(I)
50    CONTINUE
      RETURN
      END
C ******** END OF SUBROUTINE SUCCESS ***********************
```

```
47    CONTINUE
      DO 48 I = 1,MAXWS
         QWS(I) = 0.0
48    CONTINUE
C ********** DONE INITIALIZING   ************

      CALL QUAD1 (QC,QKT,QRHS,QB,A,INPUT,QTOL,TITLE,
     &           PFILE,OBJ,X,QRC,QDUAL,QSLK,QIOUT,QWS)

C **** CALCULATE CORRELATION ********

49    CONTINUE
      INPUT(5) = 1
      IF(QIOUT(1).NE.1) RETURN
      COVAR = 0.
      DO 50 I = 1,NUM
      COVAR = COVAR + X(I)*B(I)/BULLET
50    CONTINUE

      XVAR = 0.0
      COST = 0.0
      DO 60 I = 1,NUM
         COST = COST + ABS(X(I)-OLDWT(I))
         DO 70 J = 1,NUM
            XVAR = XVAR + X(I)*X(J)*A(I,J)
70    CONTINUE
60    CONTINUE

      OBJLAST = OBJSTAR
      OBJSTAR = COVAR/(XVAR**.5)
C **** DONE WITH CORRELATION CALCULATION
      CHANGE = (OBJSTAR-OBJMAX)/ABS(OBJMAX)
      WRITE(*,990)ICOUNT,SCALE,OBJSTAR*1000,DELTA*100
990   FORMAT('+',I3,' SCALE=',F7.2,'  OBJ=',F7.2,'   =',F7.2,' %')
991   FORMAT('+',A50)
C ******** TERMINATE IF MOVE IS SMALL **********************
      IF (DELTA .LT. CHECK/5. ) RETURN
      IF (ICOUNT .GT. 6) RETURN
      WRITE(*,*)' CALLING  HESSIAN     ............'
      CALL SUCCESS (NUM)
      CALL QUAD1 (QC,QKT,QRHS,G,H,INPUT,QTOL,TITLE,
     &           PFILE,OBJ,X,QRC,QDUAL,QSLK,QIOUT,QWS)
      IF(QIOUT(1).NE.1) THEN
         DO 75 I = 1,NUM
            X(I) = XMAX(I)
75       CONTINUE
         RETURN
      END IF
C ******** CALCULATE THE CHANGE IN X ***********************
      DELTA = 0.0
      DO 80 I = 1,NUM
         DELTA = DELTA + ABS(X(I)-F(I))
```

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```
C ***************************************************************----
C *** PARAMETERS ARE USED TO DIMENSION THE COMMON ARRAYS          *
C *** IN EACH SUBROUTINE.                                        *
C ***                                                           *

C ***   ND  =  TOTAL NUMBER OF STOCK WEIGHTS BEING COMPUTED.    *
C ***   ID  =  THE MAXIMUM NUMBER OF CONSTRAINT EQUATIONS.      *
C ***   N2D =  THE DIMENSION ON WORKING AREAS ( 2 * ND )        *
C ***   KEQ =  NUMBER OF CONSTRAINTS WHICH WILL BE EQUALITIES   *

C ***   NRT =  NUMBER OF RETURNS                                *
C ***   NST =  USED FOR STATISTICS                              *

C ***   ISIZEQ = 2 * ( ND*2 + ID )**2 + 8*(ND*2+ID) +6          *
C ***   NDID = ND + ID                                          *

C ***************************************************************
C       LAST UPDATED: November 19, 1988
      IMPLICIT REAL (A-H,O-Z)
      IMPLICIT INTEGER (I-N)
      PARAMETER (KEQ = 0)
C 280
C     PARAMETER (ND =  280, ID = 6 , N2D = 560)
C     PARAMETER (NDID = 286, ISIZEQ = 645246)
C 250
C     PARAMETER (ND =  250, ID = 6 , N2D = 500)
C     PARAMETER (NDID = 256, ISIZEQ = 516126)
C 100
      PARAMETER (ND =  100, ID = 6 , N2D = 200)
      PARAMETER (NDID = 106, ISIZEQ = 86526)

      PARAMETER (NRT = 48, NST = 3)
      PARAMETER (LENGTH = 40)
      CHARACTER*(LENGTH) FILEOUT,TITLE,NAME(ND),PORTRETS,GARB,ANSWER,
     &          OLD,LIANAME,LIABIN,STOCKIN,BONDIN,IDC(ND),SIC(99)

      COMMON /ARRY/ A(ND,ND),C(ND,ID), H(ND,ND), G(ND), F(ND)
      COMMON /VECT/ B(ND),D(ID),BDL(ND),BDU(ND),X(ND),OLDWT(ND)
      COMMON /RETS/ RET(NRT,ND),ANIM(NRT),PRET(NRT),ISIC(ND),AVE(ND)
      COMMON /TRAC/ COV(NST,NST),STAT(NRT,NST),COREL(NRT,NST)
      COMMON /TRA2/ PRICE(ND),VOL(ND),CUM(ND),VAR(3),LIANAME,TITLE
      COMMON /RTNIN/FILEOUT,LIABIN,STOCKIN,BONDIN,IDC,NAME,SIC
      COMMON /DAT/  NMSAVE,NM,NSIMS,NSTOCKS,NBONDS,NSTAT,NRETS,IDUMMY,
     &              IHOLD
      COMMON /MAX/  STOCKMIN,YIMAX,SMAX,SCALE,BRET,XFACTOR,XBUPPER,
     &      XBLOWER,BULLET,TARGET,TURN,BULL1,TARG1,TURN1,PORTVAL
C  END OF COMMON.F
```

APPENDIX IV

"FASTTRACK" PROGRAM FOR ANALYZING LARGE NUMBERS OF SECURITIES IN A RAPID, EFFICIENT MANNER TO PROVIDE OPTIMUM CORRELATION OF ASSET RETURN TO A TIME DEPENDENT FINANCIAL INDEX. SUBSTANTIAL COMPUTER MEMORY STORAGE REDUCTION IS ALSO ACHIEVED.

```
      CALL DEFAULT
C ****************************************************************
C ********  THIS IS SPOT MULTI RETURNS TO FOR NEXT RUN  ********
      CONTINUE
C ********  ********  IF IFLAG(1)=1 THEN THIS IS A SINGLE RUN *****
      IF (IFLAG(1).EQ.1)    THEN
C           **********************      CALL REDPAST  TO READ  IN PARAMETERS  **
            WRITE(*,101)'CALLING     REDPAST    ...      '
            CALL REDPAST
C           **********************      CALL MODIFY  TO CHANGE  PARAMETERS  ****
            WRITE(*,101)'CALLING     MODIFY     ...      '
            CALL MODIFY
C           **********************      IFLAG(1)>=2   THEN MULTIPLE  RUN  *******
      ELSEIF  (IFLAG(1).GE.2)    THEN
            WRITE(*,101)'CALLING     MULTRUN    .......      '
            CALL MULTRUN
      END IF
C     **********************      CALL SAVDAT  TO SAVE    PAST.DAT    *****
      WRITE(*,101)'CALLING     SAVDAT    ....      '
      CALL SAVDAT
C     ****************************************************************
C     **********************      CALL CALCPARAM  TO CALC  PARAMETERS  **
      WRITE(*,101)'CALLING     CALCPARAM  .      '
      CALL CALCPARAM
C     ****************************************************************
C     **********************      CALL LIABIN  TO READ  IN RETURNS  **
```

```
C UPDATED July 10, 1989
C       COPYWRITE 1989 NATIONAL INVESTMENT SERVICES OF AMERICA
C ****************************************************************
      PROGRAM FASTRACK
C ****************************************************************
C **************    INCLUDE COMMON BLOCK FILE     ****************
      INCLUDE 'COMMON.F'
C ****************************************************************
C **************    WRITE COPYRIGHT TO SCREEN     ****************
      WRITE(*,*)'                                                  '
      WRITE(*,*)'COPYRIGHT (c) NATIONAL INVESTMENT SERVICES OF AME
      WRITE(*,*)'                          1988'
      WRITE(*,*)'                                                  '
      WRITE(*,*)'is the year that this unpublished work was origin
      WRITE(*,*)'created.  NATIONAL INVESTMENT SERVICES OF AMERICA
      WRITE(*,*)'("NISA") owns all rights to this work and intends
      WRITE(*,*)'maintain this work confidential so as to maintain
      WRITE(*,*)'work as a trade secret.  NISA may also seek to'
      WRITE(*,*)'maintain this work as an unpublished copyright.'
      WRITE(*,*)'In the event of an inadvertent or deliberate'
      WRITE(*,*)'publication NISA intends to enforce its rights'
      WRITE(*,*)'to this work under the copyright laws as a published'
      WRITE(*,*)'works.  Those having access to this work may not copy,'
      WRITE(*,*)'use, or disclose the information in this work unless'
      WRITE(*,*)'expressly authorized by NISA to do so.'
      WRITE(*,*)'                                                  '
      WRITE(*,*)'                      CONFIDENTIAL                '
      WRITE(*,*)'                                                  '
      WRITE(*,*)' PROPERTY OF NATIONAL INVESTMENT SERVICES OF AMERICA'
      WRITE(*,*)'                                                  '
      WRITE(*,*)'                  ALL RIGHTS RESERVED'
      WRITE(*,*)'                                                  '

      WRITE(*,101)'CALLING COPYRIGHT .......    '

      CALL COPYRIGHT
C ****************************************************************
C **************   READ FLAG FILE TO FIND OUT WHAT KIND OF RUN *
      WRITE(*,101)'CALLING READFLAG ...    '

      CALL READFLAG
C ****************************************************************
C **************   SET UP DEFAULT PARAMETERS     ****************
      WRITE(*,101)'CALLING DEFAULT  ...    '
```

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```
      WRITE(* 101)'CALLING     TRACKER    .......      '
      CALL  TRACKER
C     ************************        CALL  TO TRADING/TURNOVER    ROUTINE  *********
      WRITE(* 101)'CALLING     TRADE    ...........      '
      CALL  TRADE
C     ************************        CALL  TO INDUSTRY   OUTPUT            *********
      WRITE(*,101)'CALLING     INDUST    ........      '
      CALL  INDUST
C     ************************************************************************
100   WRITE(*,101)'SPANNING     SIMULATION   COMPLETE'
      IF (IFLAG(1).GE.2)    THEN
         WRITE(*,102)'DONE    WITH  RUN  NUMBER       ',ISKIP
                                          GOTO  NEXT  SPANNING   RUN
         GO TO 5
      END IF
101   FORMAT('+',A50)
102   FORMAT('+',A50,I7)
      END
C                    END  OF  MAIN  PROGRAM   SPAN1
C     ************************************************************************
C  UPDATE  05/14/89
C     ************************************************************************
C       SUBROUTINE   TRADE
C     ************************************************************************
      INCLUDE   'COMMON.F'
      PARAMETER   (MAXBUY   = 700)
      INTEGER   BUY(MAXBUY),SELL(MAXBUY)
      CHARACTER*1    ABOUND

C                    *******    CALCULATE   NEW  AND  OLD  OBJECTIVE   FUNCTIONS
C                               VALTURN  =  TOTAL  FORCED  TURNOVER
C                               ADJUST  OLD  OBJ  SO  AS  TO  REPLICATE   100%  PORT  WT
      WRITE(*,101)'CALLING     LIABIN    .....      '
      CALL  LIABIN
C     ************************        READ  IN  STOCK  RETURN  FILE  **
      IF(IFLAG(6).EQ.1)THEN
          WRITE(*,101)'CALLING     STOCKIN    ....      '
          CALL  STOCKIN
      ELSEIF(IFLAG(6).EQ.2)THEN
          WRITE(*,101)'CALLING     BINSTIN    ....      '
          CALL  BINSTIN
      ENDIF
C     ************************        CALL  BONDIN  TO READ  IN  RETURNS  **
      WRITE(*,101)'CALLING     BONDIN    .....      '
      CALL  BONDIN
C     ************************      CALL  HOLDING  FOR  CURRENT  WEIGHTS  ****
      WRITE(*,101)'CALLING     HOLDING    ....      '
      CALL  HOLDING
C     ************************      CALL  SOLVE  TO  CALCULATE    INPUT  ARRAYS  *
      WRITE(*,101)'CALLING     SOLVE    ........      '
      CALL  SOLVE
C     ************************        CALL  TO PORTFOLIO   OUTPUT      **********
      WRITE(*,*)
      WRITE(*,101)'CALLING     PORT    ..........      '
      CALL  PORT
C     ************************     IF  RUN  ABORTED  GO  TO  FINISH
      IF  (IFLAG(7).EQ.2)    GO  TO  100
C     ************************        CALL  TO STATISTICAL   TRACKING      *********
```

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```
      DO 40 I = 1,IBUY-1
           DO 50 J = I+1,IBUY
                IF( PART(BUY(J)).LT.PART(BUY(I)))       THEN
                    ITEMP  = BUY(I)
                    BUY(I)  = BUY(J)
                    BUY(J)  = ITEMP
                ENDIF
50         CONTINUE
40    CONTINUE
C                   ***      SORT  THE  SELLS     ********************

      DO 60 I = 1,ISELL-1
           DO 70 J = I+1,ISELL
C               TEST  = PART(SELL(J))    - PART(SELL(I))
                IF (PART(SELL(J)).GT.PART(SELL(I)))       THEN
                    ITEMP  = SELL(I)
                    SELL(I)  = SELL(J)
                    SELL(J)  = ITEMP
                ENDIF
70         CONTINUE
60    CONTINUE

      WRITE(10,*)
      WRITE(10,*)
      WRITE(10,109)'                        TURNOVER   = ',TURNOV*50,'    %'
      WRITE(10,*)
      WRITE(10,109)'                  TOTAL  PURCHASE  = ',TOTBU*100.0,'    %'
      WRITE(10,109)'           TOTAL  OPTIONAL  SALES  = ',TOTSEL*100.0,'    %'
      WRITE(10,109)'             TOTAL  FORCED  SELLS  = ',VALTURN*100.0,'    %'
      WRITE(10,*)
      WRITE(10,108)'    # OF  STOCKS  IN  PORTFOLIO   = ',NUMSTK
      WRITE(10,108)'                NUMBER  OF  BUYS  = ',IBUY
      WRITE(10,108)'              NUMBER  OF  SELLS   = ',ISELL
      WRITE(10,*)
      WRITE(10,109)'VARIANCE     AT  OLD  WEIGHTS   = ',VOLD*100.,'    %'
      WRITE(10,109)'VARIANCE     AT  NEW  WEIGHTS   = ',VNEW*100.,'    %'
      WRITE(10,109)'    OBJ FUNCTION  IMPROVEMENT   = ',DELTA,'    %'
      WRITE(10,*)
      WRITE(10,111)'THIS     YRS  PORTFOLIO   VALU  = $ ',PORTVAL
      WRITE(10,111)'     1989  EQUIVALENT   VALUE  = $ ',PRTVALS
      WRITE(10,*)
      WRITE(10,*)
109   FORMAT(A28,F8.2,A3)
108   FORMAT(A28,I6)
111   FORMAT(A28,F18.2)

C                 ************          WRITE  THE  BUYS        *********************

      WRITE(10,*)'                                  ***     BUY     ***'

      WRITE(10,102)('*',K     = 1,78)
```

```
      VNEW  = 0.0
      VOLD  = 0.0
      AVENEW  = 0.0
      AVEOLD  = 0.0

      DO 10 I=1,  NSTAT
           RETNEW  = 0.0
           RETOLD  = 0.0
           DO 20 J=1,NUM
             RETNEW=RETNEW+X(J)*(RET(I,J)-ANIM(I))
             RETOLD=RETOLD+OLDWT(J)*(1./(1.-VALTURN))*(RET(I,J)-ANIM(I))
20         CONTINUE
           VNEW  = VNEW  + RETNEW**2/REAL(NSTAT)
           VOLD  = VOLD  + RETOLD**2/REAL(NSTAT)
           AVENEW  = AVENEW  + RETNEW/REAL(NSTAT)
           AVEOLD  = AVEOLD  + RETOLD/REAL(NSTAT)
10    CONTINUE

      VNEW  = ((VNEW  - AVENEW**2)*12)**.5
      VOLD  = ((VOLD  - AVEOLD**2)*12)**.5

C           *****  DELTA  IS  THE  PERCENTAGE   IMPROVEMENT   IN  VARIANCE  ******

      DELTA  = 0.0
      IF(VOLD.NE.0.0)THEN
         DELTA  = (VOLD  - VNEW)/VOLD
      ENDIF
      DELTA  = DELTA  * 100.

      IBUY  = 0
      ISELL  = 0
      TURNOV  = 0.0
      TOTBU  = 0.0
      TOTSEL  = 0.0
      NUMSTK  = 0

      DO 30 I = 1,NUM
           IF(X(I).GT.0.0001)NUMSTK=NUMSTK+1
           IF((X(I)-OLDWT(I)).GT.0.00001)       THEN
                IBUY  = IBUY  + 1
                BUY(IBUY)   = I
                TOTBU=TOTBU+X(I)-OLDWT(I)
           ELSEIF((X(I)-OLDWT(I)).LT.-0.00001)       THEN
                ISELL  = ISELL  +1
                SELL(ISELL)   = I
                TOTSEL=TOTSEL+OLDWT(I)-X(I)
           ENDIF
           TURNOV  = TURNOV  + ABS(X(I)-OLDWT(I))
30    CONTINUE

C                 ******    SORT  BASED  ON  PARTIALS  *********************
C                 ******    SORT  THE  BUYS     ************************
```

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```
      WR TE(10,102)('*',K     = 1,78)

      WR TE(10,*)'      **  WEIGHTS  **  SPAN   SIC   SYMBOL',
     &           '   SHARES     PRICE   DAYS    SECURITY'

      WR TE(10,*)'    OLD    NEW   DELTA  SENS  CODE  IDC  TICK',
     &           '     (00)       ($)    VOL      NAME'

      WR TE(10,102)('*',K     = 1,78)

      TO SELL   = 0.0

      DO 90  I = 1,ISELL
           XOLD  = OLDWT(SELL(I))*100.
           XNEW  = X(SELL(I))*100.
           DELTA  = XOLD  - XNEW
C                    ****************      CALCULATE   THE  ROUND  LOT  SALE    *******
           SHARES  = 0.01*DELTA*PORTVAL/PRICE(SELL(I))
           SHARES  = REAL(NINT(SHARES/100.))

           TOTSELL   = TOTSELL  + SHARES*PRICE(SELL(I))*100.0

C                  OLD VERSION  DAYSVOL  = 100.*SHARES/DVOL(SELL(I))/1000.0

C                  ** DVOL  IS IN DAILY  DOLLAR  VOLUME  (000'S)

           IF(DVOL(SELL(I)).GT.0)THEN
               DAYSVOL   = 100.*SHARES*PRICE(SELL(I))/DVOL(SELL(I))/1000.0
           ELSE
               DAYSVOL   = 99.9
           ENDIF

           IF(RHS(SELL(I))-X(SELL(I))      .LT.  0.00001)   THEN
              ABOUND  = '*'
           ELSE
              ABOUND  = ' '
           END  IF

           IF  (DELTA  .GT.  0.01)  THEN
               WRITE(10,101)    XOLD,XNEW,-DELTA,PART(SELL(I))*1000,ABOUND,
     &                    ISIC(SELL(I)),IDC(SELL(I)),SHARES,
     &                    PRICE(SELL(I)),DAYSVOL,NAME(SELL(I))
           END  IF

90    CONTINUE


      IF(NGONE.GT.0)THEN
           WRITE(10,*)
           WRITE(10,*)'   LISTING  OF THE FORCED  SELLS  (STKS  NOT  AVILABLE)'
           WRITE(10,*)
           WRITE(10,*)'    WEIGHT  SOLD      IDCSYMBOL   '
```

```
      WRITE(10,*)'      **  WEIGHTS  **  SPAN   SIC   SYMBOL',
     &           '   SHARES     PRICE   DAYS    SECURITY'

      WRITE(10,*)'    OLD    NEW   DELTA  SENS  CODE  IDC  TICK',
     &           '     (00)       ($)    VOL      NAME'

      WRITE(10,102)('*',K     = 1,78)

      TOTBUY  = 0.0
      DO 80  I = 1,IBUY
           XOLD  = OLDWT(BUY(I))*100.
           XNEW  = X(BUY(I))*100.
           DELTA  = XNEW  - XOLD

                 ****************      CALCULATE   THE  ROUND  LOT  PURCHASE *******

           IF(PRICE(BUY(I)).GT.0)THEN
               SHARES  = 0.01*DELTA*PORTVAL/PRICE(BUY(I))
               SHARES  = REAL(NINT(SHARES/100.))
               TOTBUY  = TOTBUY  + SHARES*PRICE(BUY(I))*100.0
           ELSE
               SHARES  = 0.0
           ENDIF

                 ** DVOL  IS IN DAILY  DOLLAR  VOLUME  (000'S)

           IF(DVOL(BUY(I)).GT.0)THEN
               DAYSVOL   = 100.*SHARES*PRICE(BUY(I))/DVOL(BUY(I))/1000.0
           ELSE
               DAYSVOL   = 99.9
           ENDIF
           IF(RHS(BUY(I))-X(BUY(I))      .LT.  0.00001)   THEN
              ABOUND  = '*'
           ELSE
              ABOUND  = ' '
           END  IF

           IF  (DELTA  .GT.  0.01)  THEN
              WRITE(10,101)    XOLD,XNEW,DELTA,PART(BUY(I))*1000.,ABOUND,
     &                    ISIC(BUY(I)),IDC(BUY(I)),SHARES,
     &                    PRICE(BUY(I)),DAYSVOL,NAME(BUY(I))
           END  IF

80    CONTINUE

      WRITE(10,'(T27,A12,F14.0)')'TOTAL       BUY  $ ',TOTBUY
      WRITE(10,*)
      WRITE(10,*)
                 ************          WRITE  THE  SELLS        ************
      WRITE(10,*)'                                    ***      SELL      ***'
```

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```
      IF(NMSAVE.GE.8701)CAP=CAPS*       0.769173
      IF(NMSAVE.GE.8801)CAP=CAPS*       0.846097
      IF(NMSAVE.GE.8901)CAP=CAPS*       1.000000

C     WRITE(*,*)'IN    BOUNDS  AND  MKTCAP  = ',MKTCAP

      IF (NSTOCKS.GT.0)    THEN

          OPEN  (9,FILE   = STOKFIL,FORM='UFORMATTED',STATUS        = 'OLD')

          DO 600  I  = 1,IDUMMY
               READ  (9)  (GARB,L   = 1,3)
               READ  (9)  IGARB1,   IGARB2,   IGARB3,   IGARB4
               READ  (9)  XGARB1,   XGARB2,   XGARB3,   XGARB4
               READ  (9)  XGARB1,   XGARB2,   XGARB3,   XGARB4
               READ  (9)  ISTART
               READ  (9)  ISTOP
               DO 610  K  = 1,ISTOP-ISTART+1
                  READ  (9)  XGARB
 610           CONTINUE
 600      CONTINUE
C                                              READ  IN STOCK  DATA

          ISTK=0

          DO 700  I  = 1,NSTOCKS
C                                              READ  IN LINE  1 (NAME)
 783           INEXT=0
               READ  (9,END   = 785)  NAME(I)
               ILEN  = 1
               GARB  = '
 790           IF  (NAME(I)(ILEN:ILEN)     .EQ.  ' ')THEN
                    ILEN  = ILEN+1
                    GO TO 790
               ELSE
                    GARB(1:LENGTH)    = NAME(I)(ILEN:LENGTH)
               END  IF
               NAME(I)   = GARB
               WRITE  (*,112)  I,NAME(I)
C                                                   READ  IN LINE  2 (CUSIP)
               READ  (9,END   = 785)  GARB
C                                                   READ  IN LINE  3 (IDC,TICK)   & TRIM
               READ  (9,END   = 785)  GARB
               IDC(I)  = '          '

               ILEN  = 1
 791           IF(GARB(ILEN:ILEN).EQ.'      ')  THEN
                    ILEN  = ILEN  + 1
                    IF((ILEN+3).GT.LENGTH)      GOTO  793
                    GOTO  791
               ENDIF
```

```
               WRITE(10,*)'     ----------          ---------  '
               DO 107  I=1,NGONE
                    WRITE(10,106)VAL(I)*100.0,IDCSYM(I)
 107           CONTINUE
          ENDIF

          WRITE(10,*)
          WRITE(10,'(T27,A12,F14.0)')'TOTAL        SELL  $',TOTSELL
          WRITE(10,'(T27,A12,F14.0)')'NET       BUY  =  $',TOTBUY   - TOTSELL
          RETURN

 101      FORMAT(1X,3F6.2,F6.3,A1,I3,1X,A9,1X,F6.0,1X,F8.3,1X,F4.1,1X,A18)
 102      FORMAT(1X,78A1)
 106      FORMAT(F9.4,11X,A10)

          END

C*****************          END  OF  SUBROUTINE     TRADE         ****************

C  ****  THIS  SUBROUTINE   READS  IN  STOCK  DATA  FROM  AN  UNFORMATTED   FILE  ****

          SUBROUTINE   BINSTIN

C  ********************************************************************

C               IFIRST  IS FIRST  MONTH  OF DATA  NEEDED  FOR MATRIX
C               ILAST  IS LAST  MONTH  OF SIMULATION
C
          INCLUDE   'COMMON.F'

C
C                                                  READ  IN  DUMMY  STOCK  DATA
C                                                  THIS  IS  TO  READ  PAST

          CAPS=XCONS(4)

C                   SET  UP  CAP  TO  BE  REPRESENTATIVE    OF  TIME  PERIOD
C                   THE  SCALARS   ARE  REP  OF  CAPS  HISTORYS

          IF(NMSAVE.LT.7401)CAP=CAPS*       0.192000
          IF(NMSAVE.GE.7501)CAP=CAPS*       0.153557
          IF(NMSAVE.GE.7601)CAP=CAPS*       0.192555
          IF(NMSAVE.GE.7701)CAP=CAPS*       0.230769
          IF(NMSAVE.GE.7801)CAP=CAPS*       0.246268
          IF(NMSAVE.GE.7901)CAP=CAPS*       0.269348
          IF(NMSAVE.GE.8001)CAP=CAPS*       0.384192
          IF(NMSAVE.GE.8101)CAP=CAPS*       0.384776
          IF(NMSAVE.GE.8201)CAP=CAPS*       0.423789
          IF(NMSAVE.GE.8301)CAP=CAPS*       0.461685
          IF(NMSAVE.GE.8401)CAP=CAPS*       0.615490
          IF(NMSAVE.GE.8501)CAP=CAPS*       0.538418
          IF(NMSAVE.GE.8601)CAP=CAPS*       0.692179
```

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```
 801            CONTINUE

                DO 810 K = 1,IREAD
                    READ (9) RET(K,I)
                         ****    ADJUST  OCTOBER  1987 **********
                    IF(K+NM-NSTAT-1.EQ.     94)THEN
                        IF(K.LE.NSTAT)RET(K,I)=RET(K,I)/2.97
                    END IF

                         *** IF STOCK NON GOES AWAY DURING SIM PERIOD
                         *** THEN THE RETURNS TO MONEY MARKET TYPE LEVEL

                    IF(K.GT.NSTAT.AND.RET(K,I).LT.-1.0)THEN
                        RET(K,I)=0.005
                    ENDIF

 810            CONTINUE

                DO 1200 J = 1,ISTOP-ILAST
                    READ (9) XGARB
1200            CONTINUE
                                IF INEXT=1(MKTCAP   TOO SMALL)READ  NEXT  STOCK
          IF(INEXT.EQ.1)GOTO    783
          NSTK=NSTK+1
 700      CONTINUE

          NSTOCKS = NSTK
          NUM = NSTOCKS+NBONDS

      ENDIF

      CLOSE(1)

      RETURN

         ***      IF END OF FILE WAS HIT ON STOCKS - RESET NUM AND CONTINUE  ***
 555  NSTOCKS = I-1
      NUM = NSTOCKS+NBONDS

      CLOSE(1)

      RETURN

      CLOSE(9)

 112  FORMAT('+','STOCK    # ',I5,'  IS ',A40)

      END

 **********    END OF SUBROUTINE   BINSTIN   ****************************
 **********************************************************************
```

```
 491            IEN = 1
                IF(GARB(ILEN+IEN:ILEN+IEN).NE.'       ')THEN
                    IEN = IEN + 1
                    GOTO 491
                ENDIF

                IDC(1)(1:IEN)    = GARB(ILEN:ILEN+IEN-1)

                ILEN = ILEN + IEN + 1
 792            IF (GARB(ILEN:ILEN).EQ.'      ') THEN
                    ILEN = ILEN + 1
                    IF ((ILEN+3).GT.LENGTH)    GOTO 793
                    GOTO 792
                ENDIF

                IEN = 1
 492            IF(GARB(ILEN+IEN:ILEN+IEN).NE.'       ')THEN
                    IEN = IEN + 1
                    GOTO 492
                ENDIF

                IDC(1)(6:6+IEN-1)    = GARB(ILEN:ILEN+IEN-1)

 793            CONTINUE
C                                           READ IN LINE 4 (SIC)
                READ (9,END=  785)  ISIC(I),   IGARB1,   IGARB2,   IGARB3
                IF(ISIC(I).GT.99)    ISIC(I)  = INT (ISIC(I)/100)
C                                           READ IN LINE 5 (PRICE,SPREAD)
                READ(9,END   = 785)PRICE(I),SPREAD(I),XGARB1,XGARB2
C                                           READ IN LINE 6 (MARKET  CAP,VO
                READ(9,END   = 785)XMKTCAP(I),DVOL(I),XGARB1,XGARB2


                IF(XMKTCAP(I).LT.CAP)INEXT=1

C                                           READ IN LINE 7 (FIRST  RETURN)
                READ (9,END  = 785)  ISTART
C                                           READ IN LINE 8 (LAST  RETURN)
                READ (9,END  = 785)  ISTOP

C                       TEST FOR ENOUGH  RETURNS  TO SATISFY  NRETS

                ICHECK  = NM-NRETS-ISTART
                IF(ICHECK.LT.0)    NRETS  = NM  -  ISTART
                IF(NRETS.LT.NSTAT)     ICHECK  = IFIRST-ISTART

                DO 800 J = 1,ICHECK
                    READ (9) XGARB
 800            CONTINUE

                DO 801 J = 1,NRETS-NSTAT
                    READ(9)  XGARB
```

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```
      READ(13,'(A30)')OLDFILE
      CLOSE(13)

      RETURN
C                          ****      STOP   DONE  WITH  MULTI  RUN       **********
99    CLOSE(13)
      WRITE(*,*)'DONE    WITH  MULTIPLE   RUN  ********************'

      STOP

101   FORMAT  (A20)

      END

**********                  END  OF  SUBROUTINE     MULTRUN        ******************


C  ******  THIS  SUBROUTINE   SETS  UP  VARIABLE   VALUES   ************
      SUBROUTINE   CALCPARAM
C ***************************************************************************
      INCLUDE  'COMMON.F'

      NM  = NMSAVE
      NM  = (INT(NM/100)-80)*12+(NM-INT(NM/100)*100)
      IREAD  = NSTAT+NSIMS

      IF(NSTOCKS.GT.0)THEN
        KBUPPER  = SMAX
      END IF


      NUM  = NSTOCKS+NBONDS
      IF(NUM.GT.NMAX)THEN
          WRITE(*,*)'   WARNING   NUM >',NMAX,'   TOO BIG  FOR  PROGRAM'
          STOP
      ENDIF

      ICO  = ID
      KE  = KEQ
      KKK  = KE
      IA  = ND
      ICC  = ND
      IH  = N2D

      IFIRST  = NM-NSTAT
      ILAST  = NM+NSIMS-1

      BULLI  = BULLET
      TARGI  = TARGET
      TURNI  = TURN
```

```
      SUBROUTINE   MULTRUN
C ***************************************************************************
      INCLUDE  'COMMON.F'
      CHARACTER*30   XTITL,XFLOUT,XLIBIN,XSTKIN,XBNDIN,MULTIN

      IF(INITIAL.EQ.0)THEN
        WRITE(*,*)
        WRITE(*,'(1X,A40,$)')'     ENTER  NAME  OF  MULTI  FILE(i.e.   LTSIO)
        READ(*,'(A30)')MULTIN
        INITIAL  = 1
      ENDIF

      OPEN  (13,FILE  = MULTIN  ,STATUS  = 'OLD')

C     IF  (INITIAL.EQ.0)THEN
C         ISKIP=0
C         GOTO  30
C     ENDIF

      DO  10  I = 1,  ISKIP
          DO  20  J = 1,18
              READ(13,'(A1)',END    = 99)GARB
20        CONTINUE
10    CONTINUE

30    CONTINUE
      READ(13,101,END    = 99)TITLE
      READ(13,101,    END  = 99)  FILEOUT
      READ(13,101,    END  = 99)  LIAFIL
      READ(13,101,    END  = 99)  STOKFIL
      READ(13,101,    END  = 99)  BONDFIL
      READ(13,*,    END  = 99)  NMSAVE
      READ(13,*,    END  = 99)  NSIMS
      READ(13,*,    END  = 99)  NSTOCKS
      READ(13,*,    END  = 99)  NBONDS
      READ(13,*,    END  = 99)  IDUMMY
      READ(13,*,    END  = 99)  STOCKMIN
      READ(13,*,    END  = 99)  YIMAX
      READ(13,*,    END  = 99)  SMAX
      READ(13,*,    END  = 99)  NSTAT
      READ(13,*,    END  = 99)  NRETS
      READ(13,*,    END  = 99)  BULLET
      READ(13,*,    END  = 99)  TARGET
      READ(13,*,    END  = 99)  TURN

      ISKIP  = ISKIP+1

      CLOSE(13)

      OPEN(13,FILE='PAST.DAT',STATUS='OLD')
      READ(13,*)GARB
```

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```
      ICHANGE  = 0
      XBLOWER  = 0.0
      XBUPPER  = 3.0
      SMAX  = XBUPPER

C                                  PRTVALS  IS PORTVAL  IN 1989 DOLLARS
C                                  IT IS SCALED  IN SUB.  BOUNDS
      PRTVALS  = XCONS(1)

      RETURN

      END

C  ********** .  END OF SUBROUTINE   DEFAULT   ****************************

C  **********   THIS SUBROUTINE   READS  IN STOCK  DATA  ********************
      SUBROUTINE   STOCKIN
C  ***************************************************************

C              IFIRST  IS FIRST  MONTH  OF DATA NEEDED  FOR MATRIX
C              ILAST  IS LAST  MONTH  OF SIMULATION
C
      INCLUDE  'COMMON.F'

C                                          READ  IN DUMMY  STOCK  DATA
C                                          THIS  IS TO READ  PAST

      CAPS=XCONS(4)

C                SET  UP  CAP  TO BE  REPRESENTATIVE    OF TIME  PERIOD
C                THE  SCALARS   ARE  REP  OF  CAPS  HISTORYS

      IF(NMSAVE.LT.7401)CAP=CAPS*      0.192000
      IF(NMSAVE.GE.7501)CAP=CAPS*      0.153557
      IF(NMSAVE.GE.7601)CAP=CAPS*      0.192555
      IF(NMSAVE.GE.7701)CAP=CAPS*      0.230769
      IF(NMSAVE.GE.7801)CAP=CAPS*      0.246268
      IF(NMSAVE.GE.7901)CAP=CAPS*      0.269348
      IF(NMSAVE.GE.8001)CAP=CAPS*      0.384192
      IF(NMSAVE.GE.8101)CAP=CAPS*      0.384776
      IF(NMSAVE.GE.8201)CAP=CAPS*      0.423789
      IF(NMSAVE.GE.8301)CAP=CAPS*      0.461685
      IF(NMSAVE.GE.8401)CAP=CAPS*      0.615490
      IF(NMSAVE.GE.8501)CAP=CAPS*      0.538418
      IF(NMSAVE.GE.8601)CAP=CAPS*      0.692179
      IF(NMSAVE.GE.8701)CAP=CAPS*      0.769173
      IF(NMSAVE.GE.8801)CAP=CAPS*      0.846097
      IF(NMSAVE.GE.8901)CAP=CAPS*      1.000000

      IF(CAP.EQ.0)CAP=200000000.0

      BULLET  = BULLET*ABS(BULLET)/1000.
      IF  (TURN1.EQ.100.)THEN
         TURN  = 0.0
      ELSE
C        XNUM  = 0.10
         TURN  = .0001  * (100./(TURN1+.01)-100.0/100.01)
C                              A TURN1  OF  .2  YIELDS  A TURN  = .4
      END  IF

      RETURN

      END

C  ******  END OF SUBROUTINE   CALCPARAM  ********************************

C  ******  THIS SUBROUTINE   READS  IN FLAG  FILE  **************************
      SUBROUTINE   READFLAG
C  ***************************************************************
      INCLUDE  'COMMON.F'

      OPEN(9,FILE='FLAG.NIS')
      DO  100  I=1,10
         READ(9,*)IFLAG(I)
 100  CONTINUE
      DO  200  I=1,10
         READ(9,*)XCONS(I)
 200  CONTINUE
      DO  300  I=1,10
         READ(9,'(A)')AFLAG(I)
 300  CONTINUE

      CLOSE(9)

      RETURN

      END

C  ******  END OF SUBROUTINE   READFLAG*********************************

C  *******  THIS SUBROUTINE   SETS  UP  DEFAULT  PARAMETERS  ****************
      SUBROUTINE   DEFAULT
C  ***************************************************************
      INCLUDE  'COMMON.F'

C     DEFAULT  READ  IN OF  24  MONTHS  PRIOR   = NSTAT,  NRESTS  FOR B( ) ****

      NSTAT  = 24
      NRETS  = 24
      BULLET  = 0.0
      TARGET  = 1.
      TURN  = 100.
      ITYPE  = 1
```

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```
                ILEN = ILEN + IEN + 1
792             IF (GARB(ILEN:ILEN).EQ.'      ') THEN
                    ILEN = ILEN + 1
                    IF ((ILEN+3).GT.LENGTH)     GOTO 793
                    GOTO 792
                ENDIF

                IEN = 1
492             IF(GARB(ILEN+IEN:ILEN+IEN).NE.'       ')THEN
                    IEN = IEN + 1
                    GOTO 492
                ENDIF

                IDC(I)(6:6+IEN-1)    = GARB(ILEN:ILEN+IEN-1)

793             CONTINUE
C                                           READ IN LINE 4 (SIC)
                READ (9,*,END=   785) ISIC(I)
                IF(ISIC(I).GT.99)     ISIC(I) = INT (ISIC(I)/100)
C                                   READ IN LINE 5 (PRICE,SPREAD)
                READ(9,*,END   = 785)PRICE(I),SPREAD(I)
C                                   READ IN LINE 6 (MARKETCAP,VOL)
                READ(9,*,END   = 785)XMKTCAP(I),DVOL(I)
                IF(XMKTCAP(I).LT.CAP)INEXT=1
C                                   READ IN LINE 7 (FIRST RETURN)
                READ (9,*,END  = 785) ISTART
C                                   READ IN LINE 8 (LAST RETURN)
                READ (9,*,END  = 785) ISTOP

C                   TEST FOR ENOUGH RETURNS TO SATISFY NRETS **

                ICHECK = NM-NRETS-ISTART
                IF(ICHECK.LT.0)    NRETS = NM - ISTART
                IF(NRETS.LT.NSTAT)    ICHECK = IFIRST-ISTART

                DO 800 J = 1,ICHECK
                    READ (9,111)  GARB
800             CONTINUE

                DO 801 J = 1,NRETS-NSTAT
                    READ(9,*)GARB
801             CONTINUE

                DO 810 K = 1,IREAD
                    READ (9,*) RET(K,I)
C                       ****  ADJUST OCTOBER 1987 ********************
                    IF(K+NM-NSTAT-1.EQ.    94)THEN
                        IF(K.LE.NSTAT)RET(K,I)=RET(K,I)/2.97
                    END IF

C                       *** IF STOCK NON GOES AWAY DURING SIM PERIOD
C                       *** THEN THE RETURNS TO MONEY MARKET TYPE LEVEL
```

```
                WRITE(*,*)'IN   BOUNDS AND MKTCAP = ',MKTCAP

                IF (NSTOCKS.GT.0)   THEN

                    OPEN (9,FILE = STOKFIL,  STATUS = 'OLD')

                    DO 600 I = 1,IDUMMY
                        READ (9,111)  (GARB,L  = 1,6)
                        READ (9,*)  ISTART
                        READ (9,*)  ISTOP
                        DO 610 K = 1,ISTOP-ISTART+1
                            READ (9,*)  XGARB
610                     CONTINUE
600                 CONTINUE
                                                READ IN STOCK DATA

                    NSTK=0
                    DO 700 I = 1,NSTOCKS
                                                READ IN LINE 1 (NAME)
783                     INEXT=0
                        READ (9,111,END  = 785)  NAME(I)
                        ILEN = 1
                        GARB = '
790                     IF (NAME(I)(ILEN:ILEN)    .EQ. ' ')THEN
                            ILEN = ILEN+1
                            GO TO 790
                        ELSE
                            GARB(1:LENGTH)   = NAME(I)(ILEN:LENGTH)
                        END IF
                        NAME(I)  = GARB
                        WRITE (*,112)  I,NAME(I)
                                                READ IN LINE 2 (CUSIP)
                        READ (9,111,END  = 785)  GARB
                                                READ IN LINE 3 (IDC,TICK)&  TRIM
                        READ (9,111,END  = 785)  GARB
                        IDC(I) = '                '

                        ILEN = 1
791                     IF(GARB(ILEN:ILEN).EQ.'      ') THEN
                            ILEN = ILEN + 1
                            IF((ILEN+3).GT.LENGTH)     GOTO 793
                            GOTO 791
                        ENDIF

                        IEN = 1
491                     IF(GARB(ILEN+IEN:ILEN+IEN).NE.'       ')THEN
                            IEN = IEN + 1
                            GOTO 491
                        ENDIF

                        IDC(I)(1:IEN)    = GARB(ILEN:ILEN+IEN-1)
```

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```
      IF (NBONDS.GT.0)    THEN
          OPEN  (9,FILE   = BONDFIL,   STATUS   = 'OLD')
          DO 900  I = NSTOCKS+1,NSTOCKS+NBONDS
              READ  (9,111)   NAME(I)
              WRITE  (*,113)   I,NAME(I)
              READ  (9,111)   (GARB,L   = 1,5)
              READ  (9,*)  ISTART
              READ  (9,*)  ISTOP
C                  *****     TEST  ICHECK   FOR  ENOUGH   RETURNS   FOR  BRET  ***
              ICHECK   = NM-NRETS-ISTART
              IF(ICHECK.LT.0)     THEN
     &            WRITE(*,*)'BOND     ',I,'  DOES  NOT  CONTAIN   ENOUGH   RETS
                  FOR  NRETS'
                  STOP
              END  IF
              IF(NRETS.LT.NSTAT)     ICHECK   = IFIRST-ISTART

              DO 1000  J = 1,ICHECK
                  READ  (9,111)   GARB
1000          CONTINUE

              DO 1001  J = 1,NRETS-NSTAT
                  READ(9,*)GARB
1001          CONTINUE

              JJ  = NRETS-NSTAT

              DO 1010  K =1,IREAD
                  READ  (9,*)  RET(K,I)
                  J = JJ + K
1010          CONTINUE

              DO 1300  J = 1,ISTOP-ILAST
                  READ  (9,111)   GARB
1300          CONTINUE

 900      CONTINUE

      ENDIF

      CLOSE(9)

      RETURN

 111  FORMAT  (A40)
 113  FORMAT( '+','BOND     # ',I5,'  IS ',A40)

      END
C
C     ***********************************************************************
C                                                 END  OF  SUBROUTINE   BONDIN
C     ***********************************************************************
```

```
                  IF(K.GT.NSTAT.AND.RET(K,I).LT.-1.0)THEN
                      RET(K,I)=0.005
                  ENDIF
 810          CONTINUE

              DO 1200  J = 1,ISTOP-ILAST
                  READ  (9,111)   GARB
1200          CONTINUE
C                          IF  INEXT=1(MKTCAP    TOO  SMALL)READ   NEXT  STOCK
          IF(INEXT.EQ.1)GOTO     783
          NSTK=NSTK+1
 700      CONTINUE

          NSTOCKS   = NSTK
          NUM  = NSTOCKS+NBONDS

      ENDIF

      CLOSE(9)

      RETURN

C     ***     IF  END  OF  FILE   WAS  HIT  ON  STOCKS   -  RESET   NUM  AND  CONTINUE   ***
785   NSTOCKS   = I-1
      NUM  = NSTOCKS+NBONDS

      CLOSE(9)

      RETURN

      CLOSE(9)

 111  FORMAT  (A40)
 112  FORMAT('+','STOCK     # ',I5,'  IS ',A40)

      END

C     **********     END  OF  SUBROUTINE   STOCKIN    ****************************

C     ***********     THIS  SUBROUTINE   READS  IN  BOND  DATA  *********************
      SUBROUTINE   BONDIN
C     ***********************************************************************

C               IFIRST   IS  FIRST  MONTH  OF  DATA  NEEDED  FOR  MATRIX
C               ILAST   IS  LAST  MONTH  OF  SIMULATION
C
      INCLUDE   'COMMON.F'

C                                 READ  IN  BOND  DATA
```

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```
          DO 900 J = 1,NUM
               PRET(I)  = PRET(I)  + RET(I,J)*X(J)
 900       CONTINUE
          OBJ = OBJ + (PRET(I)-ANIM(I))**2/REAL(NSTAT)
          AVEDIFF  = AVEDIFF  + (PRET(I)-ANIM(I))/REAL(NSTAT)
 800   CONTINUE

       IF  OBJ .GT. 0.0)THEN
          OBJ=((OBJ-AVEDIFF**2)*12.)**(0.5)*100
       ELSE
          OBJ=99.9
       ENDI

C              NOW CALCULATE  RETURNS  AND WEIGHTS  IN SIMULATION  PERIOD *

       DO 801 I=1,NSIMS
          PRET(I+NSTAT)=0.0
          DO 901 J=1,NUM
               PRET(I+NSTAT)    = PRET(I+NSTAT)+CUM(J)*RET(I+NSTAT,J)
 901       CONTINUE
          DO 1001 K = 1,NUM
               CUM(K)  = CUM(K)*(1.+RET(I+NSTAT,K))/(1.+PRET(I+NSTAT))
1001       CONTINUE
 801   CONTINUE

C                          WRITE  OUT THE NEW WEIGHTS  TO A FILE  CALLED  'OLD'

C        OPEN(15,FILE   = 'OLD',  STATUS  = 'OLD')
C        REWIND(15)
C        DO 140 I = 1,NUM
C        WRITE(15,940)    CUM(I)*100
C140     CONTINUE
C940     FORMAT(1X,F15.8)
C        CLOSE(15)

C                          WRITE  OUTPUT   ******************

       OPEN(10,FILE=FILEOUT,STATUS='UNKNOWN')
       REWIND(10)

       WRITE(10,*)'    NATIONAL   INVESTMENT   SERVICES  SPANNING   TECHNOLOGY'
       WRITE(10,*)'                  SIMULATION   RESULTS'
       WRITE(10,*)
       WRITE(10,*)'                    ',TITLE
       WRITE(10,*)
       WRITE(10,*)'    LIABILITY   STREAM  USED   ',LIANAME
       WRITE(10,*)
       WRITE(10,*)'              START  END   SPAN'
       WRITE(10,*)'NUMBER    WGHT   WGHT  SENSIT  SIC  IDC   TICK',
     &          'SECURITY   NAME'
       WRITE(10,*)
```

```
       SUBROUTINE   PORT
C  ***************************************************************
       INCLUDE  'COMMON.F'

C                      RESET  THE  RETURNS  TO  ORIGINAL  STATE  **

       DO 1300 J=1,NUM
          DO 1300 I=1,NSTAT
             IF(I+NM-NSTAT-1.EQ.94)RET(I,J)=RET(I,J)*2.97
 1300  CONTINUE

C                          BEGIN  OUTPUT  PROCEDURES  **************

       UANIM  = 0.0
       DO 129 I = 1,NRETS
          UANIM  = UANIM  + ANIM(I)/REAL(NRETS)
 129   CONTINUE
       UANIM  = UANIM*TARGET

       IFLAG(7)=1
       XTOT=0.
       DO 130 I=1,NUM
          XTOT=XTOT+X(I)
          CUM(I)  = X(I)
          IF(X(I).LT.   -0.001)  THEN
               WRITE(*,*)'    '
               WRITE(*,*)'**************        SPANNING  RUN ABORTED     ******'
               WRITE(*,*)'     WEIGHT  NUMBER  ',I,'  = %',X(I)*100.
               WRITE(*,*)'***************************************************'
               IFLAG(7)=2
               RETURN
          END  IF
 130   CONTINUE

       IF  (ABS(XTOT-1.0)   .GT.  0.005)  THEN
          WRITE(*,*)'    '
          WRITE(*,*)'**************        SPANNING  RUN ABORTED     ********'
          WRITE(*,*)'     TOTAL  WEIGHT  IN PORTFOLIO   = %',XTOT*100.
          WRITE(*,*)'***************************************************'
          IFLAG(7)=2
          RETURN
       END  IF


C                      CALCULATE  THE PORTFOLIO  RETURNS     **********
C                      FIRST  CALCULATE  RETURNS  FOR NSTAT  PERIOD  ****

       OBJ = 0.0
       AVEDIFF  = 0.0
       DO 800 I = 1,NSTAT
          PRET(I)  = 0.0
```

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```
      DO 250 I=NSTAT+1,IREAD
         AVE(1)=AVE(1)+ANIM(I)/REAL(NSIM)
         AVE(2)=AVE(2)+PRET(I)/REAL(NSIM)
         AVE(3)=AVE(3)+(PRET(I)-ANIM(I))/REAL(NSIM)
250   CONTINUE
C *****        CALCULATE   COVARIANCES    **********************************
      DO 950 I=1,3
         VAR(I)=0.0
         DO 950 K=NSTAT+1,IREAD
            VAR(I)=VAR(I)+(STAT(K,I)-AVE(I))**2/REAL(NSIM-1)
950   CONTINUE

C ******      CALCULATE   THE  COVARIANCE  MATRIX'S  UPPER  OFF  DIAGONAL  ****
      DO 960 I=1,3
         DO 960 J=I,3
            DO 828 K=NSTAT+1,IREAD
               CMAT(I,J)=CMAT(I,J)+((STAT(K,I)-AVE(I))
     &            *(STAT(K,J)-AVE(J)))
828         CONTINUE
            CMAT(I,J)=CMAT(I,J)/REAL(NSIM-1)
            CMAT(J,I)  = CMAT(I,J)
960   CONTINUE
C *****        CALCULATE   CORRELATIONS         ****************************
      DO 951 I=1,3
         DO 951 J=1,I
         IF(VAR(I).LE.   0.0 .OR.  VAR(J).LE.   0.0)  GO TO 951
         CORREL(I,J)=CMAT(I,J)/(VAR(I)**.5*VAR(J)**.5)
951   CONTINUE
C *****        CALCULATE   CUMULATIVE   RETURNS       ************************
      PRET(NSTAT)=100
      ANIM(NSTAT)=100
      DO 569 I=NSTAT+1,IREAD
         XX=PRET(I)
         YY=ANIM(I)
         PRET(I)=PRET(I-1)*(1+XX)
         ANIM(I)=ANIM(I-1)*(1+YY)
569   CONTINUE

      IF(VAR(1).NE.   0.0)    BETA  = CMAT(1,2)/VAR(1)
      ALPHA  = AVE(2)  - BETA*AVE(1)

      SST =     0.0
      SSE =     0.0
      DO 952 I = NSTAT+1,IREAD
         SSE  = SSE  +  (ALPHA+BETA*STAT(I,1)-STAT(I,2))**2
         SST  = SST  +  (STAT(I,2)-AVE(2))**2
```

```
      XRET=0.0
      DO 131 I=1,NUM
         IF(IFLAG(9).EQ.2.AND.X(I).LT.       0.0001)GOTO   631
         WRITE(10,16)I,X(I)*100,CUM(I)*100,PART(I)*100,
     &                  ISIC(I),IDC(I),NAME(I)
631      XRETI  = AVE(I)   + UANIM
         XRET  = XRET  + X(I)*AVE(I)
131   CONTINUE
16    FORMAT(1X,I4,1X,2F6.3,F7.3,I4,1X,A9,1X,A36)

      XRET  = XRET*12.0*100.0

      WRITE(10,*)
      WRITE(10,649)    OBJ,  XRET
649   FORMAT(1X,'   MINIMUM  STD DEV =',F10.4,'    EXPECTED   RETURN  =',F10.4)
      WRITE(10,*)

      RETURN
      END

C                        END  OF  SUBROUTINE   PORT
C     ***************************************************************
C     ***************************************************************
      SUBROUTINE   TRACKER
C     ***************************************************************
      INCLUDE   'COMMON.F'


C ******       SET  AVERAGES   AND  COVARIANCES    TO ZERO   ******************
      DO 400 I=1,3
         AVE(I)=0.0
         DO 400 J=1,3
            CMAT(I,J)=0.0
400   CONTINUE

C ***   SET  STAT  ARRAY   1 = LIABILITY,   2 = PORTFOLIO,   3 = DIFFERENCES   **
      DO 250 I=1,IREAD
         STAT(I,1)=ANIM(I)
         STAT(I,2)=PRET(I)
         STAT(I,3)=(PRET(I)-ANIM(I))
250   CONTINUE


C *****        GO AROUND  STATISTICS   IF NSIM  < 3
      IF(NSIMS.LT.3)GOTO     318

C *****        CALCULATE   AVERAGES        **********************************
C *****        SET  NSIM  TO 2 FOR   STATISTICS   IF NSIMS.LT.1       *********

      NSIM  = NSIMS
      IF(NSIMS.LT.1)    NSIM  = 2
```

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```
988     FORMAT(1X,A12,10X,F10.6,8X,F10.2,'       %')
989     FORMAT(1X,A12,10X,F10.6)

C *****       WRITE  AVERAGES  AND  VARIANCES  OF  1-LIAB,  2-PORT,  3-DIFFS  **

      WRITE(10,*)
      WRITE(10,*)
      WRITE(10,*)'ANNUAL     RETURNS:                MEAN                    STD  DEV'
      WRITE(10,*)

       DO  990  I = 1,3
          AVE(I)  = (AVE(I)*12)*100
          VAR(I)  = ((VAR(I)*12)**.5)*100
990    CONTINUE

       WRITE(10,916)    'LIABILITY',AVE(1),VAR(1)
       WRITE(10,916)    'PORTFOLIO',AVE(2),VAR(2)
       WRITE(10,916)    'DIFFERENCE',AVE(3),VAR(3)
916   FORMAT(1X,3X,A11,9X,F9.2,'       %',10X,F9.2,'   %')

C *****       WRITE  PARAMETERS  FOR  THE  RUN  ****************************

       WRITE(10,*)
       WRITE(10,*)
       WRITE(10,*)'          PARAMETERS  FOR  THIS  RUN  WERE:  '
       WRITE(10,*)
       WRITE(10,101)   TITLE
       WRITE(10,102)   FILEOUT
       WRITE(10,103)   LIAFIL
       WRITE(10,104)   STOKFIL
       WRITE(10,105)   BONDFIL
       WRITE(10,106)   NMSAVE
       WRITE(10,107)   NSIMS
       WRITE(10,108)   NSTOCKS
       WRITE(10,109)   NBONDS
       WRITE(10,110)   IDUMMY
       WRITE(10,111)   STOCKMIN
       WRITE(10,112)   YIMAX
       WRITE(10,113)   SMAX
       WRITE(10,114)   NSTAT
       WRITE(10,115)   NRETS
       WRITE(10,116)   BULL1
       WRITE(10,117)   TARG1
       WRITE(10,118)   TURN1

101   FORMAT(1X,'   1)  SPANNING  RUN  TITLE          ',  A30)
102   FORMAT(1X,'   2)  OUTPUT  FILENAME             ',  A30)
103   FORMAT(1X,'   3)  LIABILITY  STREAM  FILE      ',  A30)
104   FORMAT(1X,'   4)  STOCK  RETURN  FILE          ',  A30)
105   FORMAT(1X,'   5)  BOND  RETURN  FILE          ',  A30)
106   FORMAT(1X,'   6)  MONTH  SIMULATION  BEGINS    ',   I6)
107   FORMAT(1X,'   7)  NUMBER  OF  MONTHS  SIMULATED  ',  I6)
```

```
952     CONTINUE

       IF(NSIMS.GT.2)    STDERR  = (SSE/REAL(NSIMS-2))**.5
       IF(SST.NE.0.0)    RSQ  = 1 - SSE/SST

C*************************************************************************
C *****       BEGIN  WRITING  THE  TRACKER  OUTPUT  **********************

 318   WRITE(10,*)'   TRACKER  OUTPUT  FILE  '
       WRITE(10,*)
       WRITE(10,*)'      MONTH        LIA          PORT          DIF'
       WRITE(10,*)

C *****       WRITE  MONTH,  LIABILITY  RET,  PORTFOLIO  RET,  DIFFERENCE  ****
       DO  700  I=NSTAT+1,IREAD
           ISTAT  = I-(NSTAT+1)
           WRITE(10,612)ISTAT+NM,(STAT(I,J),J=1,3)
 612       FORMAT(1X,3X,I4,3F13.10)
 700   CONTINUE

C *****       WRITE  CUMULATIVE  RETURNS  ****************************

       WRITE(10,*)
        WRITE(10,886)
 886   FORMAT(1X,'CUMMULATIVE     VALUES  OF  LIABILITIES  AND  ASSETS'/,
      ./,'  MONTH      LIABILTIES          PORTFOLIO',/)

       DO  847  I=NSTAT,IREAD
           ISTAT  = I-NSTAT-1
           WRITE(10,328)ISTAT+NM,ANIM(I),PRET(I)
 328       FORMAT(1X,I5,7X,F7.3,10X,F7.3)
 847   CONTINUE
 837   CONTINUE

C *****       WRITE  STATISTICS  BASED  ON  SIMULATIONS  MONTHS  ***********

       WRITE(10,*)
        WRITE(10,*)'**********          STATISTICAL  SUMMARY       **********'
        WRITE(10,985)NM,NM+NSIMS-1
 985   FORMAT(/,'       STATISTICS  BASED  ON  MONTHS  ',I4,'  THROUGH',I4),

C *****       WRITE  ALPHA,BETA,STDERR,CORREL,AND      R-SQUARED  ***********

       WRITE(10,*)
       WRITE(10,987)'ALPHA',ALPHA,'ANNUAL',ALPHA*1200
       WRITE(10,989)'BETA',BETA
       WRITE(10,988)'STD     ERR',STDERR,STDERR*100
       WRITE(10,989)'CORRELATION',COREL(2,1)
       WRITE(10,988)'R-SQUARED',RSQ,RSQ*100
 987   FORMAT(1X,A12,10X,F10.6,A8,F10.2,'       %')
```

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```
      SIC(25)  = 'PAPER  AND ALLIED  PRODUCTS'
      SIC(27)  = 'PRINTING  PUBLISHING  AND A.P.'
      SIC(28)  = 'CHEMICAL  AND ALLIED  PROD.'
      SIC(29)  = 'PETROLEUM  REFIN. & REL.  PROD.'
      SIC(30)  = 'RUBBER  AND MISC.  PLAST.  PROD.'
      SIC(31)  = 'LEATHER  & LEATHER  PRODUCTS'
      SIC(32)  = 'STONE  CLAY  GLASS  & CONC.  PROD.'
      SIC(33)  = 'PRIMARY  METAL  INDUSTRIES'
      SIC(34)  = 'FAB.  METAL  PROD.  EX.  M.&T.E.' -
      SIC(35)  = 'MACHINERY  EXCEPT  ELECTRICAL'
      SIC(36)  = 'ELE.  AND ELE.  MACH.'
      SIC(37)  = 'TRANSPORTATIONS  EQUIPMENT'
      SIC(38)  = 'MEAS.  ANAL.  & CONT.  INST.  ETC.'
      SIC(39)  = 'MISC.  MANUFACTURING  IND.'
      SIC(40)  = 'RAILROAD  TRANS.'
      SIC(41)  = 'LOC.  AND SUB.  TRANS.  & HPT'
      SIC(42)  = 'MOTOR  FREIGHT  TRANS.  AND WARE.'
      SIC(43)  = 'U.S.  POSTAL  SERVICE'
      SIC(44)  = 'WATER  TRANSPORTATION'
      SIC(45)  = 'TRANSPORTATION  BY AIR'
      SIC(46)  = 'PIPE  LINES EX.  NATURAL  GAS'
      SIC(47)  = 'TRANSPORTATION  SERVICES'
      SIC(48)  = 'COMMUNICATION'
      SIC(49)  = 'ELECTRIC  GAS AND SANIT.  SERV.'
      SIC(50)  = 'WHOLESALE  TRADE-DURABLE  GOODS'
      SIC(51)  = 'WHOLESALE  TRADE-NONDUR.  GOODS'
      SIC(52)  = 'BUILDING  MAT.  HARD.  GAR.  SUPP.'
      SIC(53)  = 'GENERAL  MERCH.  STORES'
      SIC(54)  = 'FOOD  STORES'
      SIC(55)  = 'AUTOMOTIVE  DEAL AND GAS.  SS'
      SIC(56)  = 'APPAREL  AND ACCESS.  STORES'
      SIC(57)  = 'HOME  FURN.  AND EQUIP.  STORES'
      SIC(58)  = 'EATING  AND DRINKING  PLACES'
      SIC(59)  = 'MISCELLANEOUS  RETAIL'
      SIC(60)  = 'BANKING'
      SIC(61)  = 'CRED.  AGEN.  OTH.  THAN BANKS.'
      SIC(62)  = 'SEC.  AND COMM.  BROK.  DEEXSE'
      SIC(63)  = 'INSURANCE  CARRIERS'
      SIC(64)  = 'INS.  AGENTS  BROK.  SERV.'
      SIC(65)  = 'REAL  ESTATE'
      SIC(66)  = 'COMB.  RE INS.  LOANS  & LAW  OFF.'
      SIC(67)  = 'HOLD.  AND OTHER  INV.  COMP.'
      SIC(70)  = 'HOTELS  ROOM.  HOUSES  CAMP  AOLP'
      SIC(72)  = 'PERSONAL  SERVICES'
      SIC(73)  = 'BUSINESS  SERVICES'
      SIC(75)  = 'AUTO.  REPAIR  SERV.  AND GAR.'
      SIC(76)  = 'MISC.  REPAIR  SERVICES'
      SIC(78)  = 'MOTION  PICTURES'
      SIC(79)  = 'AMUSE.  AND REC.  SERV.  EX.  MP'
      SIC(80)  = 'HEALTH  SERVICES'
      SIC(81)  = 'LEGAL  SERVICES'
      SIC(82)  = 'EDUCATIONAL  SERVICES'
```

```
108   FORMAT(1X,'  8) NUMBER  OF STOCKS                ',  I6)
109   FORMAT(1X,'  9) NUMBER  OF BONDS                 ',  I6)
110   FORMAT(1X,'10)   STOCKS  TO READ  PAST           ',  I6)
111   FORMAT(1X,'11)   MINIMUM  STOCK  HOLDING      %  ',F6.2)
112   FORMAT(1X,'12)   MAXIMUM  INDUSTRY  HOLDING   %  ',F6.2)
113   FORMAT(1X,'13)   MAXIMUM  STOCK  HOLDING      %  ',F6.2)
114   FORMAT(1X,'14)   NSTAT                           ',  I6)
115   FORMAT(1X,'15)   NRETS                           ',  I6)
116   FORMAT(1X,'16)   BULLET                          ',F6.2)
117   FORMAT(1X,'17)   TARGET                          ',F6.2)
118   FORMAT(1X,'18)   TURNOVER  FACTOR                ',F6.2)

C *****       WRITE  HISTORICAL   DATA  USED  TO  MAKE  RUN    **********
      WRITE(10,*)
      WRITE(10,*)'   PORTFOLIO  CONSTRUCTED  UPON  THE  FOLLOWING  DATA:'
      WRITE(10,*)
      WRITE(10,*)'      MONTH        LIA          PORT          DIF'
      WRITE(10,*)
      DO 300  I=1,NSTAT
         WRITE(10,612)I+NM-(NSTAT+1),(STAT(I,J),J=1,3)
300   CONTINUE

      RETURN

      END
C                                 END  OF  SUBROUTINE   TRACKER
C     ***************************************************************
C     ***************************************************************
      SUBROUTINE   INDUST
C     ***************************************************************

      INCLUDE   'COMMON.F'

      SIC(1)  = 'AGRICULTURAL   PRODUCTION-CROPS'
      SIC(2)  = 'AGRICULTURAL   PROD.-LIVESTOCK'
      SIC(7)  = 'AGRICULTURAL   SERVICES'
      SIC(8)  = 'FORESTRY'
      SIC(9)  = 'FISHING  HUNTING  AND TRAPPING'
      SIC(10)  = 'METAL  MINING'
      SIC(11)  = 'ANTHRACITE   MINING'
      SIC(12)  = 'BITUMINOUS   COAL & LIGNITE  MIN.'
      SIC(13)  = 'OIL  & GAS  EXTRACTION'
      SIC(14)  = 'MIN.  & QUARRY.  OF NONMET.  MIN.'
      SIC(15)  = 'BUILD.  CONST.-G.  C. & O.  B.'
      SIC(16)  = 'CONST.  OTH THAN  B.C.-G.C.'
      SIC(17)  = 'CONST.-SPEC.   TRADE  CONT.'
      SIC(20)  = 'FOOD  KINDRED  PRODUCTS'
      SIC(21)  = 'TOBACCO  MANUFACTURERS'
      SIC(22)  = 'TEXTILE  MILL  PRODUCTS'
      SIC(23)  = 'APP.  & OTH.  FIN.  PROD.  MFFAOSM'
      SIC(24)  = 'LUMBER  & WOOD  PROD.  EX.  FURN.'
      SIC(25)  = 'FURNITURE  AND FIXTURES'
```

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```
      SUBROUTINE   LIABIN
C *****************************************************************
      INCLUDE  'COMMON.F'

      OPEN  (9,FILE  = LIAFIL,  STATUS  = 'OLD')

      READ  (9,111)  LIANAME
      WRITE(*,"('+',A50)")LIANAME
      DO 200  I = 1,5
         READ  (9,111)  GARB
200   CONTINUE

      READ  (9,*)  ISTART
      READ  (9,*)  ISTOP

      DO 300  I = 1,IFIRST-ISTART
         READ  (9,111)  GARB
300   CONTINUE

      DO 400  I = 1,IREAD
         READ  (9,*)  ANIM(I)
400   CONTINUE

      CLOSE(9)

      RETURN

111   FORMAT  (A40)

      END

C ***********      END OF SUBROUTINE   LIASUB  ***************************
C  UPDATED  4/18/88
C*****************************************************************
C
C                  SUBROUTINE   TO WRITE OUT COPYWRITE   WARNING
C*****************************************************************
      SUBROUTINE   COPYRIGHT
C  ****************************************************************
      WRITE(*,*)'
      WRITE(*,*)'COPYRIGHT      (c) NATIONAL  INVESTMENT   SERVICES  OF AMERICA'
      WRITE(*,*)'                          1988'
      WRITE(*,*)'
      WRITE(*,*)'is   the year that this unpublished   work was originally'
      WRITE(*,*)'created.      NATIONAL  INVESTMENT   SERVICES  OF AMERICA'
      WRITE(*,*)'("NISA")     owns all rights  to this work and intends  to'
      WRITE(*,*)'maintain     this work confidential   so as to maintain  this'
      WRITE(*,*)'work    as a trade secret.    NISA may also seek  to'
      WRITE(*,*)'maintain     this work as an unpublished   copyright.'
      WRITE(*,*)'In    the event of an inadvertent   or deliberate'
      WRITE(*,*)'publication     NISA intends  to enforce  its rights'
      WRITE(*,*)'to    this work under the copyright   laws as a published'
```

```
      SIC(83)  = 'SOCIAL   SERVICES'
      SIC(84)  = 'MUSEUM  ART GALL.  BOT.  Z.G.'
      SIC(86)  = 'NONPROFIT   MEM.  ORGAN.'
      SIC(89)  = 'MISCELLANEOUS    SERVICES'
      SIC(91)  = 'EXEC.  LEG.  & GOVT  EX.  FIN.'
      SIC(92)  = 'JUSTICE   PUBLIC   SAFETY'
      SIC(93)  = 'PUB.   FIN.  TAX.  & MON.  POLICY'
      SIC(94)  = 'ADMIN.   OF HUMAN  RES.  PROGRAMS'
      SIC(95)  = 'ADMIN.   OF QUAL.  & HOUS.  PROG.'
      SIC(96)  = 'ADMIN.   OF ECONOMIC   PROGRAMS'
      SIC(97)  = 'NATIONAL   SEC.  & INTL  AFFAIRS'
      SIC(99)  = 'NONCLASSIFIABLE    ESTABLISHMENTS'

C              **********   WRITE  OUT  INDUSTRY   HOLDINGS   **********

      WRITE(10,*)
      WRITE(10,*)
      WRITE(10,*)'                  *** INDUSTRY   WEIGHTINGS   ***'
      WRITE(10,102)('*',K     = 1,78)
      WRITE(10,*)'   CODE                    INDUSTRY                        WEIGHT'
      WRITE(10,102)('*',K     = 1,78)

      DO 133  I = 1,99
         CUM(I)  = 0.0
         DO 134  J = 1,NUM
            IF (ISIC(J).EQ.I)    CUM(I)  = CUM(I)  + X(J)
134      CONTINUE
         IF (CUM(I).GT.   0.001)  THEN
            WRITE(10,135)    I,SIC(I),CUM(I)*100.
         END  IF
133   CONTINUE

      SUMWGHT=0.0
      DO 136  I = 1,NUM
         SUMWGHT   = SUMWGHT   + X(I)
136   CONTINUE

      WRITE(10,137)'                          TOTAL     =    ' ,SUMWGHT*100
      ENDFILE(10)
      CLOSE(10)

102   FORMAT(1X,78A1)
135   FORMAT(1X,I5,3X,A30,F10.2,'      %')
137   FORMAT(1X,A38,F10.2,'      %')

      RETURN

      END

C*****************          END OF SUBROUTINE    INDUST       ******************
C *****************************************************************
```

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```
C      DATA  (VOL(I),I=1,ND)/ND*0.0/
C      DATA  (CUM(I),I=1,ND)/ND*0.0/
C      DATA  (VAR(I),I=1,3)/3*0.0/
C      DATA  (SPREAD(I),I=1,ND)/ND*0.0/
C      DATA  (XMKTCAP(I),I=1,ND)/ND*0.0/
C
C      ******      SET  INTEGER   VECTORS   TO 0
C
C      DATA  (IFLAG(I),I=1,10)/10*0/
C
C      ******    SET  CHARACTER   VECTORS   TO 0
C
C      DATA  (SIC(I),I=1,99)/99*'     '/
C      DATA  (IDC(I),I=1,ND)/ND*'     '/
C      DATA  (NAME(I),I=1,ND)/ND*'     '/
C
C            ******  SET  CHARACTER   VARIABLES   TO 0
C
C     PORTRETS='     '
C     ANSWER='     '
C     GARB='     '
C     FILEOUT='     '
C     LIAFIL='     '
C     STOKFIL='     '
C     BONDFIL='     '
C     LIANAME='     '
C     TITLE='     '
C     OLD='     '
C     HOLD='     '
C
C           ******  SET  INTEGER   VARIABLES   TO 0
C
C     MMM=0
C     MAXWS=0
C     ITURN=0
C     ISKIP=0
C     ICOUNT=0
C     IPORT=0
C     ICOL=0
C     NMSAVE=0
C     NM=0
C     NSIMS=0
C     NSTOCKS=0
C     NBONDS=0
C     NSTAT=0
C     NRETS=0
C     IDUMMY=0
C     ITYPE=0
C     ICHANGE=0
C     NUM=0
C     IREAD=0
C     IFIRST=0
```

```
      WRITE(*,*)'works.     Those  having  access  to  this  work  may not copy,'
      WRITE(*,*)'use,    or  disclose   the  information   in  this  work  unless'
      WRITE(*,*)'expressly     authorized   by NISA  to  do  so.'
      WRITE(*,*)'
      WRITE(*,*)'                              CONFIDENTIAL
      WRITE(*,*)'
      WRITE(*,*)'    PROPERTY   OF  NATIONAL   INVESTMENT   SERVICES   OF  AMERICA'
      WRITE(*,*)'
      WRITE(*,*)'                          ALL  RIGHTS  RESERVED'
      WRITE(*,*)'
      XNS=1.99999999
      DO  198  I=1,30000
            XNS=XNS+1
            XNS=SQRT(XNS)
198   CONTINUE
      RETURN
      END
C ****************      END  OF  SUBROUTINE   COPYRIGHT   ******************
C
C                  THIS  SUBROUTINE   IS  COMMENTED   OUT  DUE  TO  SIZE,SPEED
C
C  ******   SUBROUTINE   INIT  INITIALIZES   ALL  VARIABLES   TO  BE  0
C
C  ***************************************************************************
C     SUBROUTINE   INIT
C  ***************************************************************************
C
C     INCLUDE   'COMMON.F'
C     PARAMETER   (NS=ND*ND,N2=ND*ID,N3=NRT*ND,N4=NST*NST,N5=NRT*NST)
C
C         ******    SET  REAL  NUMBER  VECTORS   TO  0
C
C     DATA  ((A(I,J),I=1,ND),J=1,ND)/NS*0.0/
C     DATA  ((C(I,J),I=1,ND),J=1,ID)/N2*0.0/
C     DATA  (B(I),I=1,ND)/ND*0.0/
C     DATA  (D(I),I=1,ID)/ID*0.0/
C     DATA  (BDL(I),I=1,ND)/ND*0.0/
C     DATA  (BDU(I),I=1,ND)/ND*0.0/
C     DATA  (X(I),I=1,ND)/ND*0.0/
C     DATA  (OLDWT(I),I=1,ND)/ND*0.0/
C     DATA  ((RET(I,J),I=1,NRT),J=1,ND)/N3*0.0/
C     DATA  (ANIM(I),I=1,NRT)/NRT*0.0/
C     DATA  (PRET(I),I=1,NRT)/NRT*0.0/
C     DATA  (ISIC(I),I=1,ND)/ND*0.0/
C     DATA  (AVE(I),I=1,ND)/ND*0.0/
C     DATA  ((COV(I,J),I=1,NST),J=1,NST)/N4*0.0/
C     DATA  ((STAT(I,J),I=1,NRT),J=1,NST)/N5*0.0/
C     DATA  ((COREL(I,J),I=1,NRT),J=1,NST)/N5*0.0/
C     DATA  (PRICE(I),I=1,ND)/ND*0.0/
```

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```
      ELSE  IF  (IRESPON.EQ.2)    THEN
202       WRITE(*,122)
          READ(*,'(A30)',END    = 202,  ERR = 202)  FILEOUT

      ELSE  IF  (IRESPON.EQ.3)    THEN
203       WRITE(*,123)
          READ(*,'(A30)',END    = 203,  ERR = 203)  LIAFIL

      ELSE  IF  (IRESPON.EQ.4)    THEN
204       WRITE(*,124)
          READ(*,'(A30)',END    = 204,  ERR = 204)  STOKFIL

      ELSE  IF  (IRESPON.EQ.5)    THEN
205       WRITE(*,125)
          READ(*,'(A30)',END    = 205,  ERR = 205)  BONDFIL

      ELSE  IF  (IRESPON.EQ.6)    THEN
206       WRITE(*,126)
          READ(*,*,END    = 206,  ERR = 206)  NMSAVE

      ELSE  IF  (IRESPON.EQ.7)    THEN
207       WRITE(*,127)
          READ(*,*,END    = 207,  ERR = 207)  NSIMS

      ELSE  IF  (IRESPON.EQ.8)    THEN
208       WRITE(*,128)
          READ(*,*,END    = 208,  ERR = 208)  NSTOCKS

      ELSE  IF  (IRESPON.EQ.9)    THEN
209       WRITE(*,129)
          READ(*,*,END    = 209,  ERR = 209)  NBONDS

      ELSE  IF  (IRESPON.EQ.10)    THEN
210       WRITE(*,130)
          READ(*,*,END    = 210,  ERR = 210)  IDUMMY

      ELSE  IF  (IRESPON.EQ.11)    THEN
211       WRITE(*,131)
          READ(*,*,END    = 211,  ERR = 211)  STOCKMIN

      ELSE  IF  (IRESPON.EQ.12)    THEN
212       WRITE(*,132)
          READ(*,*,END    = 212,  ERR = 212)  YIMAX

      ELSE  IF  (IRESPON.EQ.13)    THEN
213       WRITE(*,133)
          READ(*,*,END    = 213,  ERR = 213)  SMAX

      ELSE  IF  (IRESPON.EQ.14)    THEN
214       WRITE(*,134)
          READ(*,*,END    = 214,  ERR = 214)  NSTAT
```

```
C       ILAST=0
C       IHOLD=0
C
C             ******     SET  REAL  NUMBER  VARIABLES   TO 0
C
C       STOCKMIN=0.0
C       YIMAX=0.0
C       SMAX=0.0
C       SCALE=0.0
C       BRET=0.0
C       XFACTOR=0.0
C       XBUPPER=0.0
C       XBLOWER=0.0
C       BULLET=0.0
C       TARGET=0.0
C       TURN=0.0
C       BULL1=0.0
C       TARG1=0.0
C       TURN1=0.0
C       PORTVAL=0.0
C
C       RETURN
C
C       END
C
C   ******  END OF SUBROUTINE   INIT   ***************************
*************************************************************************
        SUBROUTINE   MODIFY
*************************************************************************
* **
* **    THIS  ROUTINE  MODIFIES  THE INPUT  DATA  IF NECESSARY

      INCLUDE  'COMMON.F'

10    WRITE(*,100)('    ',I = 1,5)
******************        DISPLAY  SELECTED  PARAMETERS      *****
      CALL  DISPLAY
*************************************************************

      IRESPON  = 0

      WRITE(*,120)
      READ(*,'(I2)')IRESPON

      IF(IRESPON.EQ.0)    THEN
         RETURN

      ELSE  IF  (IRESPON  .EQ.  1 ) THEN
201       WRITE(*,121)
          READ(*,'(A30)',END    = 201,  ERR = 201)  TITLE
```

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```
C       STOCKFIL          - STOCK  RETURNS  FILE
C       BONDFIL           - BOND  RETURNS  FILE
C       NMSAVE            - FIRST  MONTH  OF  SIMULATION
C       NSIMS             - NUMBER  OF  MONTHS  TO  SIMULATE
C       NSTOCKS           - NUMBER  OF  STOCK  TO  SEND  TO  OPTIMIZER
C       NBONDS            - NUMBER  OF  BONDS  TO  SEND  TO  OPTIMIZER
C       IDUMMY            - NUMBER  OF  STOCKS  TO  READ  PAST  IN  STOKFIL
C       STOCKMIN          - MINIMUM  HOLDING  IN  STOCKS
C       YIMAX             - INDUSTRY  MAXIMUM  HOLDING
C       SMAX              - SECURITY  MAXIMUM  HOLDING
C       BULLET            - CLIMBING  FACTOR
C       TARGET            - ADJUSTMENT  FACTOR  FOR  TARGET
C       TURN              - TURNOVER  FACTOR
        INCLUDE  'COMMON.F'

        PARAMETER  (MAXTXT  = 50,LINES  = 24)

        CHARACTER  HEAD*(MAXTXT),LAST*(MAXTXT),OPTIONS(LINES)*(MAXTXT)
        CHARACTER  *30  PAST
* **
* **      INITIALIZE  READ  IN  FILE:  PAST  =  'PAST.DAT'
* **
        WRITE(*,100)('  ',I = 1,5)
        WRITE(*,*)'     READING  PAST  DATA.....'
        WRITE(*,100)('  ',I = 1,5)

5       OPEN  (8,FILE  = 'PAST.DAT',  STATUS  = 'OLD',  ERR  =  10)
        READ(8,101)TITLE
        READ(8,101)FILEOUT
        READ(8,101)LIAFIL
        READ(8,101)STOKFIL
        READ(8,101)BONDFIL
        READ(8,102)NMSAVE
        READ(8,102)NSIMS
        READ(8,102)NSTOCKS
        READ(8,102)NBONDS
        READ(8,102)IDUMMY
        READ(8,103)STOCKMIN
        READ(8,103)YIMAX
        CLOSE  (8)
        RETURN

10      CONTINUE

* **      GIVE  OPTION  TO  READ  FROM  SCREEN  WITHOUT  DUMPING  OUT  OF
* **      PROGRAM  OR  TO  READ  FROM  DIFFERENT  FILE  NAME

        HEAD  = '... WARNING:  THE  PAST  DATA  FILE  DOES  NOT  EXIST'
        LAST  = '                                  ( CTRL-C  TO  ABORT  )'
        NBROP  = 2
        OPTIONS(1)  = 'INPUT  NEW  NAME  FOR  PAST  DATA  FILE'
        OPTIONS(2)  = 'READ  IN  NEW  DATA  FROM  SCREEN  '

        ELSE  IF  (IRESPON.EQ.15)  THEN
215        WRITE(*,135)
           READ(*,*,END  = 215,  ERR = 215)  NRETS

        ELSE  IF  (IRESPON.EQ.16)  THEN
216        WRITE(*,136)
           READ(*,*,END  = 216,  ERR = 216)  BULLET

        ELSE  IF  (IRESPON.EQ.17)  THEN
217        WRITE(*,137)
           READ(*,*,END  = 217,  ERR = 217)  TARGET

        ELSE  IF  (IRESPON.EQ.18)  THEN
218        WRITE(*,138)
           READ(*,*,END  = 218,  ERR = 218)  TURN

        END  IF

        GO  TO  10

20      RETURN

100     FORMAT('0',A1)
120     FORMAT('0',' ENTER  NUMBER  TO  MODIFY  <ENTER>  TO  CONTINUE:  ',$)
121     FORMAT('0',' ENTER  SPANNING  RUN  TITLE                        ',$)
122     FORMAT('0',' ENTER  FILENAME  FOR  OUTPUT                       ',$)
123     FORMAT('0',' ENTER  LIABILITY  STREAM  FILE                     ',$)
124     FORMAT('0',' ENTER  STOCK  RETURN  FILE                         ',$)
125     FORMAT('0',' ENTER  BOND  RETURN  FILE                          ',$)
126     FORMAT('0',' ENTER  MONTH  TO  BEGIN  SIMULATION                ',$)
127     FORMAT('0',' ENTER  NUMBER  OF  MONTHS  TO  SIMULATE            ',$)
128     FORMAT('0',' ENTER  NUMBER  OF  STOCKS                          ',$)
129     FORMAT('0',' ENTER  NUMBER  OF  BONDS                           ',$)
130     FORMAT('0',' ENTER  STOCKS  TO  READ  PAST                      ',$)
131     FORMAT('0',' ENTER  MINIMUM  TOTAL  STOCK  HOLDING          **  ',$)
132     FORMAT('0',' ENTER  MAXIMUM  INDUSTRY  HOLDING              **  ',$)
133     FORMAT('0',' ENTER  MAXIMUM  SINGLE  STOCK  HOLDING         **  ',$)
134     FORMAT('0',' ENTER  NSTAT                                       ',$)
135     FORMAT('0',' ENTER  NRETS                                       ',$)
136     FORMAT('0',' ENTER  BULLET                                      ',$)
137     FORMAT('0',' ENTER  TARGET                                      ',$)
138     FORMAT('0',' ENTER  TURNOVER  FACTOR                            ',$)
        END

******************        END  OF  SUBROUTINE    MODIFY       ******************
*****************************************************************
        SUBROUTINE    REDPAST
*****************************************************************
C       TITLE             - TITLE  FOR  THIS  RUN
C       FILEOUT           - OUTPUT  FILE
C       LIAFIL            - LIABILITY  RETURNS  FILE
```

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```
1       WRITE(*,101)
101     FORMAT('   1) ENTER  TITLE  FOR  SPANNING   RUN          -  ',$)
        READ(*,'(A30)',END    = 1,ERR  = 1) TITLE
        WRITE(*,*)

2       WRITE(*,102)
102     FORMAT('   2) ENTER  OUTPUT  FILE  NAME                   -  ',$)
        READ(*,'(A30)',END    = 2,ERR  = 2) FILEOUT
        WRITE(*,*)

3       WRITE(*,103)
103     FORMAT('   3) ENTER  LIABILITY   RETURNS  FILE  NAME     -  ',$)
        READ(*,'(A30)',END    = 3,ERR  = 3) LIAFIL
        WRITE(*,*)

4       WRITE(*,104)
104     FORMAT('   4) ENTER  STOCK  RETURNS  FILE  NAME          -  ',$)
        READ(*,'(A30)',END    = 4,ERR  = 4) STOKFIL
        IF (STOKFIL.EQ.'    ')STOKFIL  = 'STOCKS.PRN'
        WRITE(*,*)

5       WRITE(*,105)
105     FORMAT('   5) ENTER  BOND  RETURNS  FILE  NAME           -  ',$)
        READ(*,'(A30)',END    = 5,ERR  = 5) BONDFIL
        IF (BONDFIL.EQ.'    ')BONDFIL  = 'BONDS.PRN'
        WRITE(*,*)

6       WRITE(*,*)'   6) ENTER  YEAR  AND  MONTH  TO  BEGIN
        WRITE(*,106)
106     FORMAT('      SIMULATION   (e.g.  FEB  1987  =  8702)   -  ',$)
        READ(*,*,END    = 6,ERR  = 6) NMSAVE
        WRITE(*,*)

7       WRITE(*,107)
107     FORMAT('   7) ENTER  NUMBER  OF  MONTHS  TO  SIMULATE   -  ',$)
        READ(*,*,END    = 7,ERR  = 7) NSIMS
        WRITE(*,*)

8       WRITE(*,108)
108     FORMAT('   8) ENTER  NUMBER  OF  STOCKS  TO  USE        -  ',$)
        READ(*,*,END    = 8,ERR  = 8) NSTOCKS
        WRITE(*,*)

9       WRITE(*,109)
109     FORMAT('   9) ENTER  NUMBER  OF  BONDS  TO  USE         -  ',$)
        READ(*,*,END    = 9,ERR  = 9) NBONDS
        WRITE(*,*)

10      WRITE(*,110)
110     FORMAT('10)   ENTER  NUMBER  OF  STOCKS  READ  PAST     -  ',$)
        READ(*,*,END   =10,ERR  = 10) IDUMMY

20      CALL  MENU  (LINES,HEAD,LAST,NBROPT,OPTIONS,IRESPON)

        IF  ( IRESPON.EQ.1)    THEN
           WRITE(*,100)('    ',I  = 1,5)
           WRITE(*,104)
           READ(*,'(A30)',END     = 20,ERR  = 20)  PAST
           GO TO 5

        ELSE  IF  (IRESPON.EQ.2)    THEN
           CALL  REDSCRN
           RETURN

        END  IF

        RETURN


100     FORMAT('0',A1)
101     FORMAT(A35)
102     FORMAT(I4)
103     FORMAT(F7.2)
104     FORMAT('   NAME  FOR  PAST  DATA  FILE  ---  ',$)

        END

*****************          END  OF  SUBROUTINE     REDPAST      ****************
*************************************************************
        SUBROUTINE   REDSCRN
*************************************************************

C       TITLE           - TITLE  FOR  THIS  RUN
C       FILEOUT         - OUTPUT   FILE
C       LIAFIL          - LIABILITY   RETURNS  FILE
C       STOKFIL         - STOCK  RETURNS   FILE
C       BONDFIL          - BOND  RETURNS   FILE
C       NMSAVE          - FIRST  MONTH  OF  SIMULATION
C       NSIMS           - NUMBER  OF  MONTHS  TO  SIMULATE
C       NSTOCKS         - NUMBER  OF  STOCK  TO  SEND  TO  OPTIMIZER
C       NBONDS          - NUMBER  OF  BONDS  TO  SEND  TO  OPTIMIZER
C       IDUMMY          - NUMBER  OF  STOCKS  TO  READ  PAST  IN  STOKFIL
C       STOCKMIN        - MINIMUM   HOLDING   IN  STOCKS
C       YIMAX           - INDUSTRY   MAXIMUM   HOLDING

      INCLUDE   'COMMON.F'

* **       DEFAULT   NAMES  FOR  STOCK  AND  BOND  FILES
* **       STOCKS.PRN          &    BONDS.PRN


        WRITE(*,113)('    ',I  = 1,12)
113     FORMAT('0',A1)
```

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```
101     FORMAT(1X,'  1) SPANNING   RUN  TITLE                 ', A30)
102     FORMAT(1X,'  2) OUTPUT  FILENAME                      ', A30)
103     FORMAT(1X,'  3) LIABILITY   STREAM  FILE              ', A30)
104     FORMAT(1X,'  4) STOCK  RETURN  FILE                   ', A30)
105     FORMAT(1X,'  5) BOND  RETURN  FILE                    ', A30)
106     FORMAT(1X,'  6) MONTH  TO BEGIN  SIMULATION           ',  I6)
107     FORMAT(1X,'  7) NUMBER  OF  MONTHS  TO  SIMULATE      ',  I6)
108     FORMAT(1X,'  8) NUMBER  OF  STOCKS                    ',  I6)
109     FORMAT(1X,'  9) NUMBER  OF  BONDS                     ',  I6)
110     FORMAT(1X,'10)  STOCKS  TO  READ  PAST                ',  I6)
111     FORMAT(1X,'11)  MINIMUM  STOCK  HOLDING               ',  I6)
112     FORMAT(1X,'12)  MAXIMUM  INDUSTRY  HOLDING           % ',F6.2)
113     FORMAT(1X,'13)  MAXIMUM  SINGLE  STOCK  HOLDING      % ',F6.2)
114     FORMAT(1X,'14)  NSTAT                                % ',F6.2)
115     FORMAT(1X,'15)  NRETS                                 ',  I6)
116     FORMAT(1X,'16)  BULLET                                ',  I6)
117     FORMAT(1X,'17)  TARGET                                ',F6.2)
118     FORMAT(1X,'18)  TURNOVER  FACTOR                      ',F6.2)
        END                                                   ',F6.2)
******************      END  OF  SUBROUTINE   DISPLAY   ******************

*************************************************************************
        SUBROUTINE  SAVDAT
*************************************************************************
* **
* **    THIS  ROUTINE  SAVE  THE  FILE  FOR  LATER  USE
* **

        INCLUDE   'COMMON.F'

C       WRITE(*,100)('     ',I  = 1,7)
        WRITE(*,104)'        SAVING  DATA  TO  FILE:   PAST.DAT    .......'
C       WRITE(*,100)('     ',I  = 1,5)

        OPEN(8,FILE    = 'PAST.DAT',STATUS     = 'OLD')
        WRITE(8,101)TITLE
        WRITE(8,101)FILEOUT
        WRITE(8,101)LIAFIL
        WRITE(8,101)STOKFIL
        WRITE(8,101)BONDFIL
        WRITE(8,102)NMSAVE
        WRITE(8,102)NSIMS
        WRITE(8,102)NSTOCKS
        WRITE(8,102)NBONDS
        WRITE(8,102)IDUMMY
        WRITE(8,103)STOCKMIN
        WRITE(8,103)YIMAX
        CLOSE  (8)

        RETURN

100     FORMAT('0',A1)
```

```
        WRITE(*,*)

11      WRITE(*,111)
111     FORMAT('11)   ENTER  MINIMUM  STOCK  HOLDING          - % ',$)
        READ(*,*,END    = 11,ERR   = 11)  STOCKMIN
        WRITE(*,*)

12      WRITE(*,112)
112     FORMAT('12)   ENTER  MAXIMUM   INDUSTRY  HOLDING      - % ' ,$)
        READ(*,*,END    = 12,ERR   = 12)  YIMAX
        WRITE(*,*)

        RETURN

100     FORMAT(A35)

        END
******************      END  OF  SUBROUTINE   REDSCRN     ******************

*************************************************************************
        SUBROUTINE   DISPLAY
*************************************************************************
* **
* **    THIS  ROUTINE  DISPLAYS  SELECTED  PARAMETERS  FOR  SPANNING  RUN
* **

        INCLUDE  'COMMON.F'

        WRITE(*,*)'********       CURRENTLY   SELECTED   PARAMETERS       ********'
        WRITE(*,100)
        WRITE(*,101)   TITLE
        WRITE(*,102)   FILEOUT
        WRITE(*,103)   LIAFIL
        WRITE(*,104)   STOKFIL
        WRITE(*,105)   BONDFIL
        WRITE(*,106)   NMSAVE
        WRITE(*,107)   NSIMS
        WRITE(*,108)   NSTOCKS
        WRITE(*,109)   NBONDS
        WRITE(*,110)   IDUMMY
        WRITE(*,111)   STOCKMIN
        WRITE(*,112)   YIMAX
        WRITE(*,113)   SMAX
        WRITE(*,114)   NSTAT
        WRITE(*,115)   NRETS
        WRITE(*,116)   BULLET
        WRITE(*,117)   TARGET
        WRITE(*,118)   TURN

        RETURN

100     FORMAT('0',A1)
```

```
10     WRITE(*,*)'    '
* **
* **    PRINT  MENU
       WRITE(*,*)HEADER
       WRITE(*,*)'    '

       DO  20  I = 1,NBROPT
       WRITE(*,'(1X,I2,2H)      ,$)') I
       WRITE(*,*)OPTION(I)
20     CONTINUE

       WRITE(*,*)   LAST
* **
* **    BLANK  OUT  REST  OF  SCREEN
       DO  25  I = 1,IMAX
25     WRITE(*,*)'    '
* **
* **    REQUEST   RESPONSE
       WRITE(*,*)'    '
       WRITE(*,*)'    '
30     WRITE(*,999)
999    FORMAT('    SELECT  NUMBER  OF  OPTION  --->  ',$)
* **    RESPONSE   SET  TO  ZERO  IN  CASE  OF  CARRIAGE   RETURN
       RESPON  = 0
       READ  (*,'(I2)',END   = 40,ERR  = 5)  RESPON
       IF  (RESPON.LT.0.OR.RESPON.GT.NBROPT)        THEN
          WRITE(*,*)'   OPTION  OUT  OF  RANGE'
          GO  TO  30
       END  IF
40     RETURN
       END
C**********                END  OF  SUBROUTINE     MENU          **********

C ********   SET  UP  PROBLEM   FOR  OPTIMIZER   ***************************
       SUBROUTINE   SOLVE
C **********************************************************************
       INCLUDE   'COMMON.F'

       WRITE(*,"('+',A50)")'IN     SOLVE  ...'
C ********    SET  THE  MAXIMUM   SIZE  FOR  THE  OPTIMIZER   ***************

            DELSTAR   = 0.005
            DELSTAR   = DELSTAR/1000000.
            DISTMAX   = 0.40

C ********    ISOLVE  COUNTS   THE  NUMBER   OF  RUNS,   ICOUNT  THE  ITERATIONS   ***
       ISOLVE   = ISOLVE  + 1
       ICOUNT   = 0
       ITEST  = 0

C ********    CALL  BOUNDS   TO  SET  INDUSTRY   AND  SECURITY   BOUNDS  **********
```

```
101    FORMAT(A35)
102    FORMAT(I4)
103    FORMAT(F7.2)
104    FORMAT('+',A50)

       END

**********                END  OF  SUBROUTINE     SAVDAT          **********
C**********************************************************************
       SUBROUTINE   MENU  (LINES,HEADER,LAST,NBROPT,OPTION,RESPON)
C**********************************************************************

* **
* **   PURPOSE:   TO  PRINT  A  MENU  AND  READ  RESPONSE
* **
* **
* **
* **   VARIABLE   DEFINITIONS
* **   LINES           LINESIZE   OF  SCREEN
* **   HEADER          TITLE  LINE  FOR  MENU
* **   LAST            LAST  LINE  OF  MENU
* **   NBROPT          NUMBER  OF  OPTIONS
* **   OPTION          LIST  OF  OPTIONS
* **                   DIMENSIONED    OPTION(*)*(*)     SO  LENGTH
* **                   OF  CHARACTER   STRINGS   AND  ARRAY  SENT  BY
* **                   CALLING   PROGRAM
* **   RESPON          NUMERIC   RESPONSE
* **   I               MISCELLANEOUS     INDEX
* **   IMAX            NUMBER  OF  BLANK  LINES,   TOP  AND  BOTTON
* **
* **
* **   OVERALL   SPECIFICATIONS
       IMPLICIT   REAL  (A-Z)
       INTEGER   MAXTXT
       PARAMETER   (MAXTXT   = 50)
* **
* **   CALL  SPECIFICATIONS
       CHARACTER   OPTION(*)*(MAXTXT),HEADER*(MAXTXT),LAST*(MAXTXT)
       INTEGER   NBROPT,RESPON,LINES
* **
* **   LOCAL  SPECIFICATIONS
       INTEGER   I,IMAX
* **
* **
* **   PRINT  BLANK  UPPER  SCREEN
       IMAX  = (LINES-NBROPT-7)/2+1
       IF  (IMAX.LT.0)    THEN
          WRITE(*,*)'TOO     MANY  OPTIONS   TO  FIT  SCREEN   SIZE'
          STOP
       END  IF
5      DO  10  I = 1,IMAX
```

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```
            NBEST = NBLST
            DO 10 I = 1, NUM
               X(I) = XO(I)
10          CONTINUE
         END IF

         IF(ITEST .GT. 20 .OR. DISTMAX .LT. 0.00005) THEN
            CALL PARTIAL
            IF (DISTMAX .LT. 0.00005) WRITE(*,*)
     &          '************ TERMINAL STEP SIZE ************'
            RETURN
         ENDIF

      GO TO 999
      END IF

      DO 20 I = 1, NUM
         XO(I) = X(I)
20    CONTINUE
      OBJLAST = OBJ
      NBLST = NBEST
      GO TO 999

      RETURN

      END
********  END OF SOLVE  ***********************************************
*******************  BOUNDS CALCULATION SUBROUTINE  ********************
      SUBROUTINE BOUNDS
**************************************************************************

      INCLUDE 'COMMON.F'

      DAYSVOL=XCONS(2)
      PCNT=XCONS(3)


      WRITE(*,"('+',A50)")'IN BOUNDS...'

            SET UP PORTVAL TO BE REPRESENTATIVE OF TIME PERIOD
            THE SCALARS ARE REP OF S&P ANNUAL DOLLAR TRADING VOLUME

      IF(NMSAVE.LT.7401) PORTVAL=PRTVALS*      0.040000
      IF(NMSAVE.GE.7501) PORTVAL=PRTVALS*      0.046557
      IF(NMSAVE.GE.7601) PORTVAL=PRTVALS*      0.085555
      IF(NMSAVE.GE.7701) PORTVAL=PRTVALS*      0.082769
      IF(NMSAVE.GE.7801) PORTVAL=PRTVALS*      0.102268
      IF(NMSAVE.GE.7901) PORTVAL=PRTVALS*      0.125348
      IF(NMSAVE.GE.8001) PORTVAL=PRTVALS*      0.155192
      IF(NMSAVE.GE.8101) PORTVAL=PRTVALS*      0.273776
      IF(NMSAVE.GE.8201) PORTVAL=PRTVALS*      0.232789
      IF(NMSAVE.GE.8301) PORTVAL=PRTVALS*      0.406685
```

```
      CALL BOUNDS

C ********  CALL COVAR:INITIALIZE  LI(I), CALC AVERAGES, CALC COVARS ***
C ********  IFLAG(5)=1 FOR FULL COVARIANCE, IFLAG(5)=2 FOR OUTLIER REMOVAL
      IF(IFLAG(5).EQ.1)THEN
         CALL COVAR
      ELSEIF(IFLAG(5).EQ.2)THEN
         CALL COVAI
      ENDIF
C ********  IF A STARTING POINT IS NEEDED, CALL STARTPT ***************
      CALL STARTPT

C ********  CALL CALCOBJ TO CALCULATE OBJECTIVE FUNCTION AT START ****
      CALL CALCOBJ
      OBJLAST = OBJ

C ***************************************************************
C ********  CYCLE BACK TO THIS POINT IF NOT AT OPTIMAL ***************
C ***************************************************************

999   CONTINUE

C ********  CALL PARTIAL  ****************************************
      CALL PARTIAL
C ********  CALL MOVE_X TO MOVE FROM CURRENT TO NEXT POINT **********
      CALL MOVE_X
C ********  CALL CALCOBJ TO CALCULATE OBJECTIVE FUNCTION VALUE *****
      CALL CALCOBJ

      ICOUNT = ICOUNT + 1
      DELTA = 100.
      OBJ1 = OBJ * 1000.
      IF (OBJLAST .NE. 0.0) THEN
         DELTA = -100.*(OBJ-OBJLAST)/ABS(1+OBJLAST)
      END IF

      WRITE(*,"('+',12X,2I5,A15,F10.5,A15,E10.5)")
     &      ISOLVE,ICOUNT,'OBJ = ',OBJ1,'DELTA(%) = ',DELTA


      IF (DELTA .LE. DELSTAR) THEN

         IF (ICOUNT .EQ. ICNT+1) THEN
            ITEST = ITEST + 1
         ELSE
            ITEST = 0
         END IF

         ICNT = ICOUNT

         IF (DELTA .LT. 0.0) THEN
         DISTMAX = DISTMAX * 0.4
```

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```
            RHS(I)  = RHSMAX

            DO 20 J = 1, ID
               CONS(J,I)   = 0.0

C ********    (1) - SUM OF THE WEIGHTS  EQUALS  1.0 **********************
               IF (J .EQ. 1) CONS(J,I)  = 1.0

C ********    (2) - SUM OF SIC CODES  48,49  LT INDUSTRY  BOUND  **********
               IF (J .EQ. 2) THEN
                  IF( ISIC(I)  .EQ. 48 .OR. ISIC(I)  .EQ. 49)CONS(J,I)   = 1.0
               END IF

C ********    (3) - SUM OF SIC CODES  60,63,67  LT INDUSTRY  BOUND  *******
               IF (J .EQ. 3) THEN
                  IF( ISIC(I)  .EQ. 60 .OR. ISIC(I)  .EQ. 63 .OR. ISIC(I)
     &            .EQ. 67) CONS(J,I)  = 1.0
               END IF

20          CONTINUE

10       CONTINUE


C ********   SET RIGHT HAND SIDE FOR CONSTRAINTS  AND SET TYPES *********
         RHS(NUM+1)   = 1.000
         RHS(NUM+2)   = YIMAX  / 100.
         RHS(NUM+3)   = YIMAX  /100.


C                                SET UP XLHS VECTOR

         IF(IFLAG(2).EQ.1)THEN
            DO 30 I=1,NUM
               XLHS(I)=OLDWT(I)
 30         CONTINUE
         ELSEIF(IFLAG(2).EQ.2)THEN
            DO 40 I=1,NUM
               XLHS(I)=0.0
 40         CONTINUE
         ENDIF

         RETURN

         END
C
C    ***********************************************************  END OF SUBROUTINE    BOUNDS

C ***********FULL   COVARIANCE   CALCULATION   SUBROUTINE  ********************
      SUBROUTINE   COVAR
C ***************************************************************************
```

```
         IF(NMSAVE.GE.8401)PORTVAL=PRTVALS*        0.559490
         IF(NMSAVE.GE.8501)PORTVAL=PRTVALS*        0.573418
         IF(NMSAVE.GE.8601)PORTVAL=PRTVALS*        0.773179
         IF(NMSAVE.GE.8701)PORTVAL=PRTVALS*        1.005173
         IF(NMSAVE.GE.8801)PORTVAL=PRTVALS*        1.212097
         IF(NMSAVE.GE.8901)PORTVAL=PRTVALS*        1.000000

         IF(PORTVAL.EQ.0)PORTVAL=100000000.0

C        WRITE(*,*)'IN   BOUNDS  AND  PORTVAL  = ',PORTVAL
C        WRITE(*,*)

C ********   PCNT - PARAMETER  FOR MAX HOLDING  IN A COMPANY:  4%  ********
C ********   DAYSVOL  - PARAMETER  FOR MAX # TRADING  DAYS  IN A STOCK  *****

         DO 10 I = 1, NUM

C                           SET UP RHS VECTOR

C ********   RHS(I)  IS THE RIGHT HAND SIDE CONSTRAINT  VECTOR  ***********
            RHS(I)  = 0.0

C ********   SET RHSMIN  EQUAL  TO SMALLEST:  UPPER  BOUND,  TRADING  VOLUME,
C ********   PERCENT  OF  THE  COMPANY                    **********************
            RHSMAX  = XBUPPER/100.

C***************************************************************************
C***************************************************************************

            IF (DVOL(I)  .GT.  0.)  THEN
               IF (DAYSVOL*1000.*DVOL(I)/PORTVAL       .LT.  RHSMAX)  THEN
                  RHSMAX  = DAYSVOL*1000.*DVOL(I)/PORTVAL
               END IF
            END IF

            IF (XMKTCAP(I)   .GT.  0.)  THEN
               IF ((PCNT/100.)*1000.*XMKTCAP(I)/PORTVAL        .LT.  RHSMAX)  THEN
                  RHSMAX  = (PCNT/100.)*1000.*XMKTCAP(I)/PORTVAL
               END IF
            END IF
C ********   SET  THE  MINIMUM  INVESTED  IN A STOCK  BY USING  PORTVAL  ******
            IF ( PORTVAL  .GT.  1.0E+9)  THEN
               RHSMIN  = 0.0005
            ELSE IF ( PORTVAL  .LT.  1.0E+8)  THEN
               RHSMIN  = 0.005
            ELSE
               RHSMIN  = 0.0055  - (5.0E-12)*PORTVAL
            END IF
            IF (RHSMAX  .LT.  RHSMIN)  RHSMAX  = 0.0
CC***************************************************************************
```

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```
C ********   FIRST  SORT  THE  COVARIANCES   ********************************
      DO 20  I = 1,  NUM
         X(I)  = XLHS(I)
         XO(I)  = XLHS(I)
         DO 25  K = 1,  ID
            IF(CONS(K,I)    .EQ.  1.0)SLK(K)=SLK(K)-X(I)
25       CONTINUE
         DO 30  J = I+1,  NUM
            IF  (COV(LI(J))    .GT.  COV(LI(I)))    THEN
              LITEMP  = LI(I)
              LI(I)  = LI(J)
              LI(J)  = LITEMP
            END  IF
30       CONTINUE

20    CONTINUE

      NBEST  = 0

C             ********   NOW  FILL  THE  X()  VECTOR  AND  SWITCH  THE  LI()  VECTOR

      DO 40  I = 1,  NUM
C ********   FILL  X(I)  IF NOT  CONSTRAINED    ********************************

         SLKMAX  = RHS(LI(J))-XLHS(LI(J))
C ********   FIND  THE  TIGHTEST   CONSTRAINT    ********************************
         DO 50  K = 1,  ID
            IF  (CONS(K,LI(J))    .EQ.  1.0)  THEN
               IF  (SLK(K)   .LT.  SLKMAX)   THEN
                  SLKMAX  = SLK(K)
               END  IF
            END  IF
50       CONTINUE

C ********   SET  THE  VARIABLE   = TO  THE  MOST  SLACK  AVAILABLE   ************
         IF  (SLKMAX   .LT.  0.00001)   GO  TO  40
C ********   NOW  REDUCE  THE  SLACK  IN  EACH  CONSTRAINT   ********************
         DO 60  K = 1,  ID
            IF  (CONS(K,LI(J))    .EQ.  1.0)  THEN
               SLK(K)  = SLK(K)  - SLKMAX
            END  IF
60       CONTINUE

         NBEST  = NBEST  + 1
         LITEMP  = LI(NBEST)
         LI(NBEST)   = LI(J)
         LI(J)  = LITEMP

         X(LI(NBEST))    = SLKMAX  + X(LI(NBEST))
         XO(LI(NBEST))    = SLKMAX  + X(LI(NBEST))

         IF  (SLK(1)   .LE.  0.00001)   RETURN
```

```
      INCLUDE  'COMMON.F'

      WRITE(*,"('+',A50)")'IN      COVAR  ...'
C                    NUM  = NSTOCKS+NBONDS
C ********   INITIALIZE   LI(I),   CALC  AVE(I),   CALC  COV(I)  ****************
      UANIM  = 0.0
      VARANIM  = 0.0

      DO 10  I = 1,  NUM
C                 ********   INITIALIZE   LI(I)  VECTOR  ******************
         LI(I)  = I

         AVE(I)  = 0.0
         COV(I)  = 0.0

         DO 20  J = 1,  NSTAT
            IF  (I  .EQ.  1)  THEN
               UANIM  = UANIM  + ANIM(J)*TARGET
               VARANIM  = VARANIM  + ANIM(J)*TARGET*ANIM(J)*TARGET
            END  IF
            IF  (RET(J,I)   .LT.  -1.0)  RHS(I)  = 0.0
            AVE(I)  = AVE(I)  + RET(J,I)
            COV(I)  = COV(I)  + RET(J,I)*ANIM(J)*TARGET
20       CONTINUE
         IF  (I  .EQ.  1)  THEN
            UANIM  = UANIM  / REAL(NSTAT)
            VARANIM  = VARANIM/REAL(NSTAT)      - UANIM*UANIM
         END  IF
         AVE(I)   = AVE(I)  / REAL(NSTAT)
         COV(I)  = COV(I)  / REAL(NSTAT)    - AVE(I)  * UANIM
10    CONTINUE

      RETURN

      END
C                                                    END  OF  SUBROUTINE   COVAR
C ********************************************************************
C ********   CALCULATE   STARTING   POINT  ********************************
      SUBROUTINE   STARTPT
C ********************************************************************
C ********   THIS  SUBROUTINE   CALCULATES   A STARTING   POINT.
C ********   THE  STARTING   POINT  IS  THEN  USED  FOR  PARTIAL

      INCLUDE  'COMMON.F'

      WRITE(*,"('+',A50)")'IN      STARTPT  ...'

C ********   SET  THE  SLACK   IN  EACH  CONSTRAINT   ************************
      DO 10  I = 1,  ID
         SLK(I)  = RHS(NUM+I)
10    CONTINUE
```

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```
      PRET(I)  = PRET(I)  - ANIM(I)*TARGET
      PAVE  = PAVE  + PRET(I)/REAL(NSTAT)
      VARPORT  = VARPORT  + PRET(I)**2

10    CONTINUE

      OBJ = VARPORT  / REAL(NSTAT)  - PAVE**2  - PAVE*BULLET
      OBJS = OBJ
      END IF
C *********
                                  END IF FOR MONTHLY

C                    IF TURNOVER  IS A FACTOR  ADD IN ITS COST
      IF(TURN.GT.0)THEN
          DO 30 I = 1, NUM
             OBJ = OBJ + TURN*(  ((X(I)-OLDWT(I))**2     +1.0E-7)  **.5)
30        CONTINUE
      ENDIF

      RETURN
      END
C ********  END OF CALCOBJ  ***************************************

C ********  CALCULATE  PARTIAL  DERIVATIVES  ***********************
      SUBROUTINE  PARTIAL
C ***************************************************************
C ********  THIS  SUBROUTINE  CALCULATES  PARTIALS  AT A POINT  ***********
      INCLUDE  'COMMON.F'
      PARAMETER  ( EPS = 0.000001)

      WRITE(*,"('+',A12)")'IN      PARTIAL  ...'
C ********  PARTIAL  W.R.T.  Xi = SUMj  (Xj * COVi,j)).   BUT THIS =
C ********  COV(i,P)  WHERE  P IS THE  PORTFOLIO  RETURN.
C ********  ==> CALCULATE  PORTFOLIO  RETURN  - THEN CALC  COVARIANCES

      DO 10 I = 1, ID
        SLK(I)  = RHS(NUM+I)
        AC(I)  = -9999.
10    CONTINUE

      IF (OBJ2  - OBJ .LE.  0.0001*EPS)  NTEST = -1

      IF (NTEST  .LE.  0)  THEN
         NUMB = NUM
      ELSE
         NUMB = INT(1.1*REAL(NBEST))
         IF (NUMB  .GT.  NUM)  NUMB = NUM
         IF (NTEST  .GT.  8) NTEST = -1
      END IF

      NTEST = NTEST + 1
```

```
40    CONTINUE

      RETURN
      END
C ********  END OF STARTPT  ***************************************
C ********  CALCULATE  OBJECTIVE  FUNCTION  VALUE  ********************
      SUBROUTINE  CALCOBJ
C ***************************************************************
C ********  THIS  SUBROUTINE  CALCULATES  OBJECTIVE  FUNCTION  VALUE  *******
      INCLUDE  'COMMON.F'

      WRITE(*,"('+',A12)")'IN      CALCOBJ  ...'

      PAVE = 0.0
      VARPORT  = 0.0
      COVPORT  = 0.0

C ********                        FOR MOVING  QUARTERLY  CALCULATIONS
      IF (IFLAG(4)  .EQ.  2) THEN
      DO 5 I = 3, NSTAT
         PRET(I)  = 0.0

         DO 6 J = 1, NUM
            IF (X(J)  .GT.  0.0)  THEN
               PRET(I)  = PRET(I)  +
     &         X(J)*((1+RET(I,J))*(1+RET(I-1,J))*(1+RET(I-2,J))-1.)
            END IF
6        CONTINUE

      PRET(I)  = PRET(I)  -
     &      ((1+ANIM(I))*(1+ANIM(I-1))*(1+ANIM(I-2))-1.)*TARGET
      PAVE  = PAVE  + PRET(I)/REAL(NSTAT-2)
      VARPORT  = VARPORT  + PRET(I)**2

5     CONTINUE

      OBJ = VARPORT  / REAL(NSTAT-2)  - PAVE**2  - PAVE*BULLET
      OBJS = OBJ
      END IF
C ********                              END IF FOR MOVING  QUARTERLY
C ********                              FOR MONTHLY  RETURNS
      IF (IFLAG(4)  .EQ.  1) THEN
      DO 10 I = 1, NSTAT
         PRET(I)  = 0.0

         DO 20 J = 1, NUM
            IF (X(J)  .GT.  0.0)  THEN
               PRET(I)  = PRET(I)  + X(J)  * RET(I,J)
            END IF
20       CONTINUE
```

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```
50          CONTINUE
20      CONTINUE

C ********    NOW  SORT  THE  PARTIALS  WITH  ZERO  WEIGHTS  ********************
        NBEST  = 0
        DO  60  I = 1,  NUMB

            IBEST  = 0
            DO  70  K = 1,  ID
                IF  (CONS(K,LI(I))    .EQ.  1.0  .AND.  SLK(K)  .LT.  100.*EPS)THEN
                    IF(PART(LI(I))    .GT.  RC(K))  IBEST  = 1
                END  IF
70          CONTINUE

            IF  (IBEST  .EQ.  0)  THEN
                NBEST  = NBEST  + 1
                LITEMP  = LI(NBEST)
                LI(NBEST)  = LI(I)
                LI(I)  = LITEMP
            END  IF

60      CONTINUE

C ********    IF  THIS  IS  A  FULL  PARTIAL  --> DO  A  FULL  SORT  **************
C **********    HEAP  SORT  FOUND  ON  PAGE  233  OF  NUMERICAL  RECIPIES  ******
C       IF  ( NBEST  .EQ.  0)  THEN
            WRITE(*,"('+',A12)")'IN      SORT_P  ...'
            LHEAP  = NBEST/2  + 1
            IR  = NBEST
110         CONTINUE
                IF(LHEAP.GT.1)THEN
                    LHEAP  = LHEAP  - 1
                    INDXT  = LI(LHEAP)
                    Q=PART(INDXT)
                ELSE
                    INDXT  = LI(IR)
                    Q=PART(INDXT)
                    LI(IR)  = LI(1)
                    IR  = IR  - 1
                    IF(IR.EQ.1)  THEN
                        LI(1)  = INDXT
                        GOTO  111
                    ENDIF
                ENDIF
                JHEAP  = LHEAP
                JHEAP  = LHEAP  + LHEAP
120         IF(JHEAP.LE.IR)THEN
                IF(JHEAP.LT.IR)THEN
                    IF(PART(LI(JHEAP)).LT.PART(LI(JHEAP+1)))JHEAP=JHEAP+1
                ENDIF
                IF(Q.LT.PART(LI(JHEAP)))THEN
```

```
            DO  20  I = 1,  NUMB
                IF  (X(LI(I))    .GT.  0.0)  THEN
                    DO  30  K = 1,  ID
                        IF  (CONS(K,LI(I))    .EQ.  1.0)  SLK(K)  = SLK(K)  - X(LI(I))
30                  CONTINUE
                END  IF

                PART(LI(I))    = 0.0
                RAVE  = 0.0
C ********                                          IF MOVING  QUARTERLY  RETURNS
                IF  (IFLAG(4)  .EQ.  2)  THEN

                DO  35  J = 3,NSTAT
                XRET=(1+RET(J,LI(I)))*(1+RET(J-1,LI(I)))*(1+RET(J-2,LI(I)))-1.
                XRET  = XRET-((1+ANIM(J))*(1+ANIM(J-1))*(1+ANIM(J-2))-1)*TARGET
                PART(LI(I))    = PART(LI(I))    + XRET*PRET(J)
                RAVE  = RAVE  + XRET/REAL(NSTAT-2)
35              CONTINUE

                PART(LI(I))=2*(PART(LI(I))/REAL(NSTAT-2)-RAVE*PAVE)-RAVE*BULLET

                END  IF
C ********                                          END  MOVING  QUARTERLY

C ********                                          IF MONTHLY  RETURNS
                IF  (IFLAG(4)  .EQ.  1)  THEN
                DO  40  J = 1,NSTAT
                PART(LI(I))=PART(LI(I))+(RET(J,LI(I))-ANIM(J)*TARGET)*PRET(J)
                RAVE  = RAVE  + (RET(J,LI(I))-ANIM(J)*TARGET)/REAL(NSTAT)
40              CONTINUE

                PART(LI(I))=2.0*(PART(LI(I))/REAL(NSTAT)-RAVE*PAVE)-RAVE*BULLET

                END  IF
C ********                                          END  MONTHLY

C                       IF  TURNOVER  IS  A  FACTOR  ADD  IN  A  COST
*******************
                IF(TURN  .GT.  0.0)  THEN
                    PARTURN  = TURN*(X(LI(I))-OLDWT(LI(I)))/
     &              ((X(LI(I))-OLDWT(LI(I)))**2+1.0E-7)**.5
                    IF  (OLDWT(LI(I))    .EQ.  0.0)  PARTURN  = TURN
                    PART(LI(I))    = PART(LI(I))    + PARTURN
                ENDIF
C                       FIND  WORST  PARTIAL  FOR  A  POSITIVE  WEIGHT  STOCK
************
                DO  50  K = 1,  ID
                    IF  (  X(LI(I))    .GT.  EPS  )  THEN
                        IF(CONS(K,LI(I)).EQ.1.0.AND.PART(LI(I)).GT.RC(K))
     &                  RC(K)=PART(LI(I))
                    END  IF
```

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```
            IF (SLK(K).LT.SLKMAX     ) SLKMAX  = SLK(K)
          END IF
20      CONTINUE

C ******  FIND LARGEST  MOVE  POSSIBLE    ******************************
        DIST = DISTXI
        IF (DIST .LT. 0) WRITE(*,*)'1'

        DP = (PART(LI(IB))    - PART(LI(I)))*10.
        IF (DP .LT. DIST) DIST = DP

        IF (SLKMAX  .LT. DIST) DIST = SLKMAX

        IF (X(LI(IB))-XLHS(LI(IB)).LT.DIST)DIST=X(LI(IB))-XLHS(LI(IB))

        IF (RHS(LI(I))-X(LI(I)).LT.DIST)DIST=RHS(LI(I))-X(LI(I))
C *******          IF THE RUN CONSIDERS  TURNOVER  PREVENT  SWINGING  ******
        IF (TURN .GT. 0.0) THEN
          IF (XO(LI(I))   .LT. OLDWT(LI(I))   .AND.
     &  OLDWT(LI(I))-X(LI(I))     .LT. DIST )DIST=OLDWT(LI(I))-X(LI(I))

          IF (XO(LI(IB))   .GT. OLDWT(LI(IB))   .AND.
     &  X(LI(IB))-OLDWT(LI(IB))     .LT. DIST )DIST=X(LI(IB))-OLDWT(LI(IB))
        END IF

        IF (DIST .LT. 0.0001*EPS)  GO TO 5

        IF (DP .LT. 0.1*PMAX)  GO TO 5

        IF (DP .GT. PMAX) PMAX = DP

C *******  CHANGE  THE  X VECTOR  AND  THE  CONSTRAINTS  ******************

        X(LI(IB))  = X(LI(IB))  - DIST
        X(LI(I))  = X(LI(I))  + DIST

        DO 30 K = 1, ID
          IF (CONS(K,LI(IB))   .EQ. 1.0 ) SLK(K)  = SLK(K)  + DIST
          IF (CONS(K,LI(I))   .EQ. 1.0 ) SLK(K)  = SLK(K)  - DIST
          IF (SLK(K)  .LT. EPS) SLK(K)  = 0.0
30      CONTINUE

C *******  TEST  FOR  TOTAL  MOVE  EXCEEDING  DISTMAX  ********************
        NMOVES = NMOVES + 1
        TOTDIST = TOTDIST - DIST
        IF (TOTDIST .LT. 0.0 .OR. NMOVES .GE. 15) GO TO 99

C *******  IF THE WORST VARIABLE  STILL HAS SLACK,  REDUCE  IT **********
        IF (ABS(XO(LI(I))-X(LI(I)))     .LT. 0.5*DISTXI  ) GO TO 5
10    CONTINUE
```

```
              LI(IHEAP)=LI(JHEAP)
              IHEAP=JHEAP
              JHEAP=JHEAP+JHEAP
            ELSE
              JHEAP=IR+1
            ENDIF
            GOTO120
          ENDIF
          LI(IHEAP)=INDXT
        GOTO  110
111     CONTINUE
C       END  IF
C ***************************************************************
        OBJ2 = OBJ
        RETURN
        END
C *******  END  OF  PARTIAL  ********************************************
C *******  MOVE  TO  A NEW  POINT  BASED  ON  PARTIALS     ***************
        SUBROUTINE  MOVE_X
C ***************************************************************
C *******  THIS SUBROUTINE  MOVES  FROM  CURRENT  POINT  TO NEW  POINT  *****

        INCLUDE  'COMMON.F'
        PARAMETER  ( EPS = 0.000001)
        WRITE(*,"('+',A12)")'IN      MOVE_X  ...'

        DISTMAX = DISTMAX  * 1.05
        IF (DISTMAX  .GT. 0.4)  DISTMAX  = 0.4
        DISTXI  = 0.15  * DISTMAX

        NMOVES  = 0
        TOTDIST  = DISTMAX
        PMAX = -9999.
C *******  BEGIN  THE  MOVE  BY  MOVING  OUT  OF  WORST  INTO  BEST  **********
        DO 10 I = 1, NBEST
          IF (RHS(LI(I))-X(LI(I))     .LT. EPS)  GO TO 10
          IB = NBEST+1

5         IB = IB - 1
          IF ( IB .LE. 1) GO TO 10

          IF (PART(LI(IB))    .LE. PART(LI(I)))   GO TO 10

C *******  TEST  PROXIMITY  TO RHS AND TOTAL  MOVEMENT  *****************
          IF (X(LI(IB))-XLHS(LI(IB))     .LT. EPS)  GO TO 5
          IF (ABS(XO(LI(IB))-X(LI(IB)))      .GT. 0.5*DISTXI)   GO TO 5

C *******  TEST  FOR  CONSTRAINT  PROXIMITY  ****************************
          SLKMAX  = 1.0
          DO 20 K = 2, ID
            IF (CONS(K,LI(I)).EQ.1.0     .AND.  CONS(K,LI(IB)).EQ.0.0)     THEN
              IF (SLK(K).LT.EPS)    GO TO 5
```

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```
                WRITE(13,*)I,COV(I)
50            CONTINUE
40          CONTINUE
10      CONTINUE
        CLOSE(13)
        RETURN

        END
C                                                    END OF SUBROUTINE   COVAI
C ***************************************************************************
*****************************************************************************
        SUBROUTINE   HOLDING
*****************************************************************************

        INCLUDE   'COMMON.F'

        CHARACTER*9   SYMBL
        CHARACTER*30   GARB2,WTFILE
C                                  RESET  OLD  WEIGHTS  TO 0
        DO 234  I=1,NUM
           OLDWT(I)=0.0
 234    CONTINUE

C                  ******IF   THIS  IS A SINGLE  RUN  READ  WEIGHT  FILE  SPECIFIED

        IF(IFLAG(1).EQ.1)THEN
999        WRITE(*,*)'   ENTER  FILENAME  CONTAINING  PORT.  WTS
     &     (i.e.  \WGT\AOSUP.WGT)'
           READ(*,'(A30)')WTFILE
           OPEN  (11,FILE   = WTFILE,STATUS    = 'OLD',ERR=999)
           READ(11,*,    END  = 888)SYMBL,VALUE
           WRITE(*,*)'
           WRITE(*,*)'   SPAN.WGT  CONTAINS  PORTFOLIO  # ',VALUE
           WRITE(*,*)'
           READ(11,*,END    = 888)GARB
           I = 0

           DO 888  L = 1,500
              READ(11,*,    END  = 888)SYMBL,VALUE
              I = I + 1
              IDCSYM(I)   = SYMBL
              VAL(I)   = VALUE
888        CONTINUE

           NIDC  = I
           ICASH  = 0
           PORTVAL   = 0.

           DO 10 I=1,NIDC
```

```
99      CONTINUE

        DO 50 I = 1, NBEST

           IF (RHS(LI(I))-X(LI(I))     .LT.  EPS)  X(LI(I))   = RHS(LI(I))
           IF (X(LI(I))-XLHS(LI(I)).LT.0.01*EPS)X(LI(I))=XLHS(LI(I))

50      CONTINUE

        RETURN
        END
C ********   END  OF  MOVE_X     ***************************************
C ***********OUTLIER     REMOVAL   COVARIANCE   CALCULATION   SUBROUTINE   *******
        SUBROUTINE   COVAI
C ***************************************************************************

        INCLUDE   'COMMON.F'

        WRITE(*,*('+',A50)*)'IN      COVAI
C                     NUM  = NSTOCKS+NBONDS
C ********   INITIALIZE   LI(I),   CALC  AVE(I),   CALC  COV(I)  ***************

        OPEN(13,FILE='TEMP.PRN',STATUS='UNKNOWN')

        DO 10 I = 1, NUM

           LI(I)  = I
           UANIM  = 0.0
           VARANIM   = 0.0
           AVE(I)   = 0.0
           COV(I)   = 0.0

           DO 40 K = 1, NSTAT
              DO 50 L = 1, NSTAT
                 DO 20 J = 1, NSTAT
                    IF (RET(J,I)   .LT.  -1.0)  RHS(I)   = 0.0
                    IF(J.EQ.K.OR.J.EQ.L)GOTO     20
                    UANIM   = UANIM   + ANIM(J)*TARGET
                    VARANIM   = VARANIM   + ANIM(J)*TARGET*ANIM(J)*TARGET
                    AVE(I)   = AVE(I)   + RET(J,I)
                    COV(I)   = COV(I)   + RET(J,I)*ANIM(J)*TARGET
20                CONTINUE

                  UANIM   = UANIM   / (REAL(NSTAT)-2.)
                  VARANIM   = VARANIM/(REAL(NSTAT)-2.)      - UANIM*UANIM

                  AVE(I)   = AVE(I)   / (REAL(NSTAT)-2.)
                  COV(I)   = COV(I)   / (REAL(NSTAT)-2.)     - AVE(I)   * UANIM
C                                CREATE   VECTOR   OF COVARIANCES
                  VCOV(I,K)=COV(I)
                  WRITE(*,*)'   K L HELD  OUT  AND  COV(I)',K,L,COV(I)
```

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```
105           FORMAT(A)
              GOTO  104
          ELSE
              GOTO  101
          ENDIF
104       REWIND(11)
          DO  90  I=1,10
              READ(11,'(A1)')GARB
 90       CONTINUE
          DO  109  I=1,NMAX
              VAL(I)=0.0
              IDCSYM(I)='    '
109       CONTINUE
          NCOUNT=0
          DO  91  I=1,NMAX
              READ(11,92)ITEMP,TEMP1,VAL(ITEMP),TEMP2,ITEMP2,
     &                   IDCSYM(ITEMP)
              IF(TEMP1.GT.0.0001)THEN
                  NCOUNT=NCOUNT+1
                  VAL(NCOUNT)=VAL(ITEMP)/100.0
                  IDCSYM(NCOUNT)=IDCSYM(ITEMP)
                  IF(NCOUNT.EQ.IOLDST)GOTO      93
              ENDIF
92            FORMAT(I5,F7.3,F6.3,F7.3,I4,1X,A5)
91        CONTINUE
93        CLOSE(11)

          IDCTEST   = 0
          NCOUNT    = 0
          VALTURN   = 0.0
          OLDTOT=0.0

          DO  21  I  =  1,IOLDST
              ITEST   = 0
              DO  31  J  =  1,NUM
                  IF(IDC(J)(1:4)    .EQ.  IDCSYM(I))   THEN
                      ITEST   =  1
                      OLDWT(J)   =  VAL(I)
                      OLDTOT=OLDTOT+OLDWT(J)
C                     WRITE(*,*)'   SYMBOL  FOUND  ',IDCSYM(I),OLDWT(J)
31                ENDIF
              CONTINUE
              IF  (ITEST.EQ.0)    THEN
                  IDCTEST   =  1
                  VALTURN=VALTURN+VAL(I)
                  OLDTOT=OLDTOT+VAL(I)
                  WRITE(*,*)'   SYMBOL  NOT  FOUND',IDCSYM(I),VAL(I)
C                 NCOUNT   =  NCOUNT+1
C                             FILL  TOP  OF  IDCSYM()&VAL    TO PRINT  OUT  IN TRADE
                  IDCSYM(NCOUNT)=IDCSYM(I)
                  VAL(NCOUNT)=VAL(I)
                  WRITE(*,*)IDCSYM(I),':SYMBL       NOT  INCL  IN RET  FILE'
```

```
              PORTVAL   =  PORTVAL   +  VAL(I)
              IF  (IDCSYM(I)    .EQ.  'CASH')THEN
                  ICASH   =  1
                  TEMP   =  VAL(I)
                  VAL(I)   =  VAL(1)
                  VAL(1)   =  TEMP
                  GARB   =  IDCSYM(I)
                  IDCSYM(I)    =  IDCSYM(1)
                  IDCSYM(1)    =  GARB
              ENDIF
10        CONTINUE
          PRTVALS=PORTVAL

          IF  (ICASH   .EQ.  0)  THEN
              WRITE(*,*)'NO    CASH  INCLUDED....PROGRAM     STOPPING'
              STOP
          ENDIF

          IDCTEST   =  0
          NCOUNT    =  0
          DO  20  I  =  2,NIDC
              ITEST   =  0
              DO  30  J  =  1,NUM
                  IF(IDC(J)(1:4)    .EQ.  IDCSYM(I))   THEN
                      ITEST   =  1
                      NCOUNT   =  NCOUNT+1
                      OLDWT(J)   =  VAL(I)   /  PORTVAL
                  ENDIF
30            CONTINUE
              IF  (ITEST   .EQ.  0)  THEN
                  IDCTEST   =  1
                  WRITE(*,*)IDCSYM(I),':SYMBL       NOT  INCL  IN RET  FILE'
              ENDIF
20        CONTINUE

          IF  (IDCTEST.EQ.1)    THEN
              WRITE(*,*)NIDC-NCOUNT-1,'SYMLS       NT  FOUND.PROG    CONTINUING'
          ENDIF
          CLOSE(11)
C         **********************        IF  MULTI   RUN  (STD)   READ  WTS  FRO  LST  RUN  *****

      ELSEIF(IFLAG(1).EQ.2)THEN
C       IF(ISKIP.GT.1)THEN
        IF(ISKIP.GE.1)THEN
          OPEN(11,FILE    =  OLDFILE,STATUS    =  'OLD')
101       READ(11,102)GARB2
102       FORMAT(A25)
          IF(GARB2.EQ.'             TOTAL   FORCED   SELLS')THEN
              READ(11,105)GARB2
              READ(11,103)IOLDST
C             WRITE(*,*)'   NUMBER  OF  OLDSTK  WTS  ',IOLDST
103           FORMAT(27X,I7)
```

```
            ENDIF
21          CONTINUE

            IF(OLDTOT.LT..99)THEN
                WRITE(*,*)'   WARNING  OLDWTS  TOTAL  < .99,  CONTINUING   '
                WRITE(*,*)'   OLDTOT  = ',OLDTOT
            ELSEIF(OLDTOT.GT.1.01)THEN
                WRITE(*,*)'   WARNING  OLDWTS  TOTAL  > 1.01,  CONTINUING   '
                WRITE(*,*)'   OLDTOT  = ',OLDTOT
            ENDIF

            NGONE=NCOUNT
            IF (IDCTEST.EQ.1)   THEN
               WRITE(*,*)'   A TOTAL  OF ',VALTURN*100.0,    ' % OF PORT  SOLD'
               WRITE(*,*)NGONE,'SYMLS     NOT  FOUND,  PROGRAM  CONTINUING'
            ENDIF
C                                        IF THE 1ST TIME THROUGHT SET OLDWT()=0

          ELSEIF(ISKIP.EQ.1)THEN
            DO 98 I=1,NUM
                OLDWT(I)=0.0
  98        CONTINUE
          ENDIF

C                        ********   IF MULTI  RUN (&OLD)  READ  WTS  FRO  OLD.

        ELSEIF(IFLAG(1).EQ.3)THEN
C           OPEN(21,FILE   = 'OLD',STATUS   = 'OLD')
            DO 94 I = 1,NUM
C               READ(21,*)OLDWT(I)
C               IF (TURN.EQ.   0.0)OLDWT(I)=0.0
C                     THIS  NEXT  LINE  ADDED  4/18/89
                OLDWT(I)=0.0
C               OLDWT(I)   = OLDWT(I)/100.
94          CONTINUE
C           CLOSE(21)
        ENDIF

        RETURN

        END

C ******************          END  OF  SUBROUTINE    HOLDING       **************
```

APPENDIX V

REINVESTMENT OF AVAILABLE CASH
BEGINNING FROM CURRENT
PORTFOLIO HOLDINGS

295	2.372	2.372	1.035	73	SMED	SMED	SHARED MED SYS CORP COM
296	1.889	1.889	1.086	38	MFS	STR	QUESTAR CORP COM
297	2.299	2.299	1.353	1	TEJN	TRC	TEJON RANCH CO DEL COM
298	3.629	3.629	1.138	80	USHC	USHC	U S HEALTHCARE INC COM
299	3.406	3.406	1.061	38	USSC	USS	UNITED STATES SURGICAL CC
300	1.375	1.375	0.947	49	WGL	WGL	WASHINGTON GAS LT CO COM
301	1.844	1.844	0.995	67	WRE	WRE	WASHINGTON REAL ESTATE IN
302	1.262	1.262	0.930	49	MFR5	MCN	MCN CORP COM

MINIMUM STD DEV = 18.8463 EXPECTED RETURN = 17.6218

TRACKER OUTPUT FILE

MONTH	LIA	PORT	DIF

CUMMULATIVE VALUES OF LIABILITIES AND ASSETS

MONTH	LIABILTIES	PORTFOLIO
115	-0.005	0.049

********** STATISTICAL SUMMARY **********

STATISTICS BASED ON MONTHS 116 THROUGH 115

ALPHA	0.000000	ANNUAL	0.00 %
BETA	0.000000		
STD ERR	0.000000		0.00 %
CORRELATION	0.000000		
R-SQUARED	0.000000		0.00 %

ANNUAL RETURNS:	MEAN	STD DEV
LIABILITY	0.00 %	0.00 %
PORTFOLIO	0.00 %	0.00 %
DIFFERENCE	0.00 %	0.00 %

PARAMETERS FOR THIS RUN WERE:

1)	SPANNING RUN TITLE	AOS 7/28/89 RUN
2)	OUTPUT FILENAME	temp.nlb
3)	LIABILITY STREAM FILE	\LIR\AOS725.LIR
4)	STOCK RETURN FILE	\RET\AOSUP.RET
5)	BOND RETURN FILE	\RET\BONDS.PRN
6)	WEIGHT FILE	\WGT\159.WGT
7)	MONTH SIMULATION BEGINS	8908
8)	NUMBER OF MONTHS SIMULATED	0
9)	NUMBER OF STOCKS	302
10)	NUMBER OF BONDS	0
11)	MINIMUM STOCK HOLDING %	100.00
12)	MAXIMUM INDUSTRY HOLDING %	19.00

IMPROVED SYTEM ANALYSIS: RE-INVEST DIVIDEND FLOWS
SIMULATION RESULTS

EXAMPLE RUN

LIABILITY STREAM USED: EXAMPLE LIABILITY

NUMBER	START WGHT	END WGHT	SPAN SENSIT	SIC	IDC	TICK	SECURITY NAME
45	3.475	3.475	1.024	27	GEN	GTE	GTE CORP COM
62	1.693	1.693	1.088	48	SBCA	SBC	SOUTHWESTERN BELL CORP COM
74	2.196	2.196	1.194	37	BA	BA	BOEING CO COM
82	3.508	3.508	1.021	20	K	K	KELLOGG CO COM
136	0.031	0.031	1.052	56	LINT	LTD	LIMITED INC COM
194	0.041	0.041	1.038	34	MAS	MAS	MASCO CORP COM
231	1.475	1.475	0.702	67	FBG1	ONE	BANC ONE CORP COM
243	2.680	2.680	1.295	29	PZL	PZL	PENNZOIL CO COM
252	2.410	2.410	0.883	49	DTE	DTE	DETROIT EDISON CO COM
260	1.204	1.204	0.926	49	BGE	BGE	BALTIMORE GAS & ELEC CO COM
261	2.835	2.835	1.069	61	FUN	FTU	FIRST UN CORP COM NASD BK INS
262	0.529	0.529	1.276	29	ASH	ASH	ASHLAND OIL INC COM
263	1.546	1.546	1.030	26	W	W	WESTVACO CORP COM
264	1.399	1.399	0.973	49	WPC	WEC	WISCONSIN ENERGY CORP COM
265	1.558	1.558	0.773	60	AHN	AHM	AHMANSON H F & CO COM
266	2.761	2.761	1.043	12	PEL	PEL	PANHANDLE EASTN CORP COM
267	2.690	2.690	0.887	49	IPC	IPC	ILLINOIS POWER CO COM
268	2.726	2.726	0.831	67	NES	NES	NEW ENGLAND ELEC SYS COM
269	0.563	0.563	0.957	49	TSG	TEP	TUCSON ELEC PWR CO COM
270	1.142	1.142	1.068	7	IFLH	IFL	IMC FERTILIZER GROUP INC COM
271	1.187	1.187	1.070	75	AGNC	AGNC	AGENCY RENT A CAR COM NASD INDL
272	0.819	0.819	0.897	49	ATA	ATG	ATLANTA GAS LT CO COM
273	2.698	2.698	1.082	30	BDG	BDG	BANDAG INC COM
274	0.451	0.451	1.349	32	BALL	BLL	BALL CORP COM
275	2.909	2.909	0.882	49	BSE	BSE	BOSTON EDISON CO COM
276	1.155	1.155	0.909	67	CALH	CAL	CALFED INC COM
277	1.700	1.700	1.058	73	CMCS	CMCS	COMCAST CORP CL A NASD INDL
278	2.093	2.093	1.678	35	LANS	COMS	3COM CORP COM NASD INDL
279	1.190	1.190	1.131	67	FPA	FPA	FIRST PA CORP COM
280	3.346	3.346	0.754	67	HCP	HCP	HEALTH CARE PPTY INVS INC COM REIT
281	2.418	2.418	1.036	8	IPT	IPT	IP TIMBERLAND LTD DEP UNIT CL A
282	2.442	2.442	1.044	27	HJH	JH	HARLAND JOHN H CO COM
283	0.182	0.182	0.935	49	KAN	KAN	KANSAS PWR & LT CO COM
284	2.694	2.694	0.896	65	KOG	KOG	KOGER PPTYS INC COM REI
285	0.535	0.535	1.152	20	LNE	LNCE	LANCE INC COM NASD INDL
286	3.172	3.172	0.885	52	LCI	LOW	LOWES COS INC COM
287	3.207	3.207	0.895	45	SAR1	LUV	SOUTHWEST AIRLS CO COM
288	3.000	3.000	0.967	67	MTRV	MT	MEDITRUST SH BEN INT
289	1.238	1.238	0.904	49	IPS	MWE	MIDWEST ENERGY CO COM
290	3.005	3.005	1.184	36	NPK	NPK	NATIONAL PRESTO INDS INC COM
291	2.755	2.755	0.994	67	RCPA	RCP	ROCKEFELLER CTR PPTYS INC COM REIT
292	0.846	0.846	1.181	23	RML	RML	RUSSELL CORP COM
293	1.158	1.158	1.157	38	SEFC	SEED	DEKALB GENETICS CORP CL B NASD INDL
294	1.256	1.256	0.889	49	SIG	SIG	SOUTHERN IND GAS & ELEC CO COM

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13)	MAXIMUM STOCK HOLDING %	3.00
14)	NSTAT	24
15)	NRETS	24
16)	BULLET	0.00
17)	TARGET	2.00
18)	TURNOVER FACTOR	4.00
19)	MAX DAYS VOLUME	2.00
20)	PORTFOLIO VAL (89 MM)	26.00
21)	MAX % STK MKT CAP	3.00
22)	MIN MKT CAP (89 MM)	2500.00
23)	MAX MKT CAP (89 MM)	1000000.00
24)	SINGLE	1
25)	1 WAY BUY	1
26)	SPAN	1
27)	MONTHLY	1
28)	FULL COVARIANCE	1
29)	FORMATTED FILES	1
30)	STATUS IS OK	1
31)	+WTS OUTPUT ONLY	2
32)	STOCKS TO SCREEN	1

PORTFOLIO CONSTRUCTED UPON THE FOLLOWING DATA:

MONTH	LIA	PORT	DIF
92	-0.0235312600	0.0048044603	0.0283357203
93	-0.0556954108	-0.0405714661	0.0151239447
94	0.0943555534	-0.1450983137	-0.2394538671
95	0.0001456921	-0.0072849635	-0.0074306554
96	0.0178604499	0.0324543230	0.0145938732
97	0.0754733980	0.0913652703	0.0158918723
98	0.0176621992	0.0246764552	0.0070142560
99	-0.0450356193	-0.0050582327	0.0399773866
100	-0.0287487004	-0.0243650582	0.0043836422
101	-0.0128774298	0.0054894658	0.0183668956
102	0.0561982282	0.0558000170	-0.0003982112
103	-0.0344604515	-0.0200813692	0.0143790822
104	-0.0011062390	0.0000485850	0.0011548240
105	0.0447797514	0.0430007204	-0.0017790310
106	0.0371330716	0.0263595097	-0.0107735619
107	-0.0318946689	-0.0176053215	0.0142893475
108	0.0158855300	0.0229464527	0.0070609227
109	0.0271665901	0.0407870896	0.0136204995
110	-0.0267152898	0.0007467365	0.0274620261
111	0.0109503297	0.0284809042	0.0175305754
112	0.0262673292	0.0394087993	0.0131414700
113	0.0461410806	0.0458422191	-0.0002988614
114	0.0783677101	0.0054350942	-0.0729326159
115	-0.0048000002	0.0486113280	0.0534113273

TURNOVER = 0.91 %

TOTAL PURCHASE = 1.83 %

TOTAL OPTIONAL SALES = 0.00 %
TOTAL FORCED SELLS = 0.00 %

OF STOCKS IN PORTFOLIO = 52
NUMBER OF BUYS = 14
NUMBER OF SELLS = 0

VARIANCE AT OLD WEIGHTS = 18.63 %
VARIANCE AT NEW WEIGHTS = 18.85 %
OBJ FUNCTION IMPROVEMENT = -1.15 %

THIS YRS PORTFOLIO VALU = $ 28062494.00
1989 EQUIVALENT VALUE = $ 28062494.00

*** BUY ***

** WEIGHTS ** OLD	NEW	DELTA	SPAN SENS	SIC CODE	SYMBOL IDC	TICK	SHARES (00)	PRICE ($)	DAYS VOL	SECURITY NAME
2.88	2.91	0.03	8.821	49	BSE	BSE	4.	17.000	0.0	BOSTON EDISON CO
2.39	2.41	0.02	8.828	49	DTE	DTE	2.	21.125	0.0	DETROIT EDISON CO
1.57	2.69	1.12	8.873	49	IPC	IPC	189.	16.625	00.0	ILLINOIS POWER CO
0.00	0.04	0.0410	.377	34	MAS	MAS	4.	30.125	0.0	MASCO CORP COM
2.74	2.76	0.0210	.431	12	PEL	PEL	2.	27.750	0.0	PANHANDLE EASTN CO
0.00	0.03	0.0310	.521	56	LINT	LTD	3.	34.875	0.0	LIMITED INC COM
1.66	1.70	0.0410	.579	73	CMCS	CMCS	4.	25.625	0.0	COMCAST CORP CL A
1.13	1.14	0.0210	.676	7	IFLH	IFL	1.	35.125	0.0	IMC FERTILIZER GRO
1.39	1.89	0.5010	.860	38	MFS	STR	37.	37.500	0.3	QUESTAR CORP COM
					TOTAL BUY $		512213.			

*** SELL ***

** WEIGHTS ** OLD	NEW	DELTA	SPAN SENS	SIC CODE	SYMBOL IDC	TICK	SHARES (00)	PRICE ($)	DAYS VOL	SECURITY NAME

TOTAL SELL $ 00.
NET BUY = $ 512213.

*** INDUSTRY WEIGHTINGS ***

CODE	INDUSTRY	WEIGHT
1	AGRICULTURAL PRODUCTION-CROPS	2.30 %
7	AGRICULTURAL SERVICES	1.14 %
8	FORESTRY	2.42 %
12	BITUMINOUS COAL & LIGNITE MIN.	2.76 %
20	FOOD KINDRED PRODUCTS	4.04 %
23	APP. & OTH. FIN. PROD. MFFAOSM	0.85 %
26	PAPER AND ALLIED PRODUCTS	1.55 %
27	PRINTING PUBLISHING AND A.P.	5.92 %

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29	PETROLEUM REFIN. & REL. PROD.	3.21 %
30	RUBBER AND MISC. PLAST. PROD.	2.70 %
32	STONE CLAY GLASS & CONC. PROD.	0.45 %
35	MACHINERY EXCEPT ELECTRICAL	2.09 %
36	ELE. AND ELE. MACH.	3.00 %
37	TRANSPORTATIONS EQUIPMENT	2.20 %
38	MEAS. ANAL. & CONT. INST. ETC.	6.45 %
45	TRANSPORTATION BY AIR	3.21 %
48	COMMUNICATION	1.69 %
49	ELECTRIC GAS AND SANIT. SERV.	17.31 %
52	BUILDING MAT. HARD. GAR. SUPP.	3.17 %
60	BANKING	1.56 %
61	CRED. AGEN. OTH. THAN BANKS.	2.83 %
65	REAL ESTATE	2.69 %
67	HOLD. AND OTHER INV. COMP.	17.49 %
73	BUSINESS SERVICES	4.07 %
75	AUTO. REPAIR SERV. AND GAR.	1.19 %
80	HEALTH SERVICES	3.63 %
	TOTAL =	99.99 %

Prior methods have required the calculation of a covarianc the return series. Here the covariance matrix is calculated to advantage of the current system. The covariance cells evaluated standard definition and the cells in the matrix are filled. The calculations produce the following array:

Covariance Matrix

	x1	x2	x3
x1	0.0525	0.0275	-.0162
x2	0.0275	0.0525	0.0188
x3	-.0162	0.0188	0.0525

The prior methodology calculates the partial derivative by weights times the entries in each row and multiplying the total b partial derivative can be calculated for x2 at the current point following manner:

Partial(x2) = 2 * (0.3*0.0275 + 0.5*0.0525 + 0.2*0.0

= 0.0765

The current system calculates the partial derivative by finc portfolio returns at the current weights for the 8 periods and the the covariance of x2 with the portfolio. The return in period(1) portfolio is:

Portfolio return(1) = 0.3*0.8 + 0.5*0.7 + 0.2*0.4

= 0.67

The other returns for periods 2 though 7 are calculated for portfolio. Then covariance between x2 and the portfolio is simply n the standard way. The result is the partial derivative of x2:

Covariance (portfolio, x2) = 0.0765

EXAMPLE ILLUSTRATING DISTINCTIONS BETWEEN

CURRENT SYSTEM AND PRIOR ART

To illustrate the current system's approach to solving an appropriate problem, a simple example is outlined to point out distinctions and improvements over prior art. The example problem objective function is to find the minimum variance portfolio relative to a standard financial target. The constraints are that the sum of the security weights must be 1.0 and the lower bound of 0.0 on each security. This example will illustrate the extraction of a search direction and outline the optimization process.

Beginning with a series of eight returns for three securities, x1, x2, and x3, the average returns are calculated for each security. The eight returns represent monthly total returns less the return on a standard financial target for each of the securities in this simple example.

Net Security Returns After Subtracting Target Returns

Period	x1	x2	x3
1	0.8	0.7	0.4
2	0.7	0.8	0.7
3	0.6	0.1	0.2
4	0.4	0.6	0.6
5	0.1	0.3	0.8
6	0.2	0.4	0.5
7	0.5	0.5	0.1
8	0.3	0.2	0.3
Average	x1	x2	x3
	0.45	0.45	0.45

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This result is identically the same as extracting the partial derivative from the full covariance matrix. However, fewer calculations are required and less computer memory is needed to obtain the partial derivatives. Mathematically, the results prove to be exactly the same.

Once the partial derivatives have been extracted for each of the variables, it is a simple matter to search for a better solution using the partials to indicate a direction which improves the objective function. The simple process of letting the partial derivatives guide a search, recalculating the partials at the new solution, and searching again, leads quickly to an optimal solution. The search proceeds downhill until the objective function can no longer improve. This is the optimal solution.

In summary, the current system requires fewer calculations to determine an optimal point and therefore can solves problems in much less time. The current system also requires much less computer memory and therefore can solve much larger problem. By analyzing more securities at once, a better solution can be achieved.

OUTPUT FROM PROGRAM

43	0.570	0.570	0.001	23	RML	RML	RUSSELL CORP	
44	3.155	3.155	00.000	73	SMED	SMED	SHARED MED SYS CORP	NASD INI
45	1.377	1.377	0.001	49	SIG	SIG	SOUTHERN IND GAS & ELEC CO	
46	2.632	2.632	0.000	45	SAR1	LUV	SOUTHWEST AIRLS CO	
47	1.569	1.569	0.001	48	SBCA	SBC	SOUTHWESTERN BELL CORP	
48	2.201	2.201	0.001	1	TEJN	TRC	TEJON RANCH CO	
49	1.291	1.291	0.001	49	TSG	TEP	TUCSON ELEC PWR CO	
50	2.246	2.246	0.001	80	USHC	USHC	U S HEALTHCARE INC	NASD INDL
51	2.118	2.118	00.000	49	UIL	UIL	UNITED ILLUM CO	
52	3.073	3.073	0.002	38	USSC	USS	UNITED STATES SURGICAL CORP	
53	1.488	1.488	0.001	49	WGL	WGL	WASHINGTON GAS LT CO	
54	1.582	1.582	0.001	49	WPC	WEC	WISCONSIN ENERGY CORP	
55	0.983	0.983	0.002	51	SEFC	SEED	DEKALB GENETICS CORP	
56	0.229	0.229	0.002	51	PTVZ	DKLB	PRIDE PETE SVCS INC	

MINIMUM STD DEV = 13.0185 EXPECTED RETURN = 9.0049

TRACKER OUTPUT FILE

MONTH	LIA	PORT	DIF

CUMMULATIVE VALUES OF LIABILITIES AND ASSETS

MONTH	LIABILTIES	PORTFOLIO
107	0.022	-0.005

********** STATISTICAL SUMMARY **********

STATISTICS BASED ON MONTHS 108 THROUGH 107

ALPHA	0.000000	ANNUAL	0.00 %
BETA	0.000000		
STD ERR	0.000000		0.00 %
CORRELATION	0.000000		
R-SQUARED	0.000000		0.00 %

ANNUAL RETURNS:	MEAN	STD DEV
LIABILITY	0.00 %	0.00 %
PORTFOLIO	0.00 %	0.00 %
DIFFERENCE	0.00 %	0.00 %

PARAMETERS FOR THIS RUN WERE:

1)	SPANNING RUN TITLE	UPDATE A.O.STEEL 12 5 88
2)	OUTPUT FILENAME	TEMP.SPN
3)	LIABILITY STREAM FILE	\LIR\AOSTEEL.LIR
4)	STOCK RETURN FILE	\RET\AOSNOV.RET

NATIONAL INVESTMENT SERVICES SPANNING TECHNOLOGY
SIMULATION RESULTS

EXAPMLE UPDATE WITH CONTROLLED TURNOVER

LIABILITY STREAM USED

NUMBER	START WGHT	END WGHT	SPAN SENSIT	SIC	IDC	TICK	SECURITY NAME	
1	3.365	3.365	0.000	35	LANS	COMS	3COM CORP	NASD INDL
2	0.992	0.992	0.001	75	AGNC	AGNC	AGENCY RENT A CAR	NASD INDL
3	1.414	1.414	00.000	60	AHN	AHM	AHMANSON H F & CO	
4	1.353	1.353	0.001	48	T	T	AMERICAN TEL & TELEG CO	
5	0.583	0.583	0.002	29	ASH	ASH	ASHLAND OIL INC	
6	1.007	1.007	0.001	49	ATA	ATG	ATLANTA GAS LT CO	NASD INDL
7	1.217	1.217	0.002	32	BALL	BLL	BALL CORP	
8	1.418	1.418	0.001	49	BGE	BGE	BALTIMORE GAS & ELEC CO	
9	1.199	1.199	0.001	60	FBG1	ONE	BANC ONE CORP	
10	3.023	3.023	0.002	30	BDG	BDG	BANDAG INC	
11	2.154	2.154	0.001	37	BA	BA	BOEING CO	
12	3.120	3.120	0.001	49	BSE	BSE	BOSTON EDISON CO	
13	1.397	1.397	0.001	35	BGG	BGG	BRIGGS & STRATTON CORP	
14	1.276	1.276	00.000	67	CALH	CAL	CALFED INC	
15	0.344	0.344	0.001	20	CKE	CKE	CASTLE & COOKE INC	
16	0.616	0.616	0.001	73	CMCS	CMCS	COMCAST CORP	NASD INDL
17	0.414	0.414	-0.001	35	CBU1	CBU	COMMODORE INTL LTD	
18	0.181	0.181	0.002	51	COSV	COST	COSTCO WHSL CORP	NASD INDL
19	1.486	1.486	0.003	51	DEK1	DKLB	DEKALB CORP	NASD INDL
20	2.015	2.015	0.002	60	FPA	FPA	FIRST PA CORP	
21	2.628	2.628	0.001	61	FUN	FUNC	FIRST UN CORP	NASD BK INS
22	3.294	3.294	0.001	27	GEN	GTE	GTE CORP	
23	3.000	3.000	0.001	67	HCP	HCP	HEALTH CARE PPTY INVS INC	
24	2.811	2.811	0.002	8	IPT	IPT	IP TIMBERLAND LTD	
25	0.211	0.211	0.001	49	KAN	KAN	KANSAS PWR & LT CO	
26	3.002	3.002	0.001	20	K	K	KELLOGG CO	
27	3.000	3.000	0.002	65	KOG	KOG	KOGER PPTYS INC	
28	0.251	0.251	0.002	20	LNE	LNCE	LANCE INC	NASD INDL
29	1.827	1.827	0.001	52	LCI	LOW	LOWES COS INC	
30	2.944	2.944	0.002	67	MTRV	MT	MEDITRUST SH BEN INT	
31	1.280	1.280	0.001	49	MFR5	MCN	MICHIGAN CONS GAS CO	COM
32	1.438	1.438	0.001	49	IPS	MWE	MIDWEST ENERGY CO	
33	3.045	3.045	0.001	36	NPK	NPK	NATIONAL PRESTO INDS INC	
34	3.100	3.100	00.000	67	NES	NES	NEW ENGLAND ELEC SYS	
35	1.098	1.098	0.001	25	OSM	OMT	OHIO MATTRESS CO DEL	
36	1.445	1.445	0.001	48	PACB	PAC	PACIFIC TELESIS GROUP	
37	2.879	2.879	0.001	12	PEL	PEL	PANHANDLE EASTN CORP	
38	2.955	2.955	0.003	29	PZL	PZL	PENNZOIL CO	
39	0.496	0.496	0.002	13	PRMK	PMK	PRIMARK CORP	
40	3.010	3.010	0.001	38	MFS	STR	QUESTAR CORP	
41	3.025	3.025	0.001	67	RCPA	RCP	ROCKEFELLER CTR PPTYS INC	
42	0.175	0.175	0.002	37	RHR	RHR	ROHR INDS INC	

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5)	BOND RETURN FILE	\RET\BONDS.PRN
6)	MONTH SIMULATION BEGINS	8812
7)	NUMBER OF MONTHS SIMULATED	0
8)	NUMBER OF STOCKS	56
9)	NUMBER OF BONDS	0
10)	STOCKS TO READ PAST	0
11)	MINIMUM STOCK HOLDING %	100.00
12)	MAXIMUM INDUSTRY HOLDING %	20.00
13)	MAXIMUM STOCK HOLDING %	3.00
14)	NSTAT	24
15)	NRITS	24
16)	BULLET	0.00
17)	TARGET	1.00
18)	TURNOVER FACTOR	100.00

PORTFOLIO CONSTRUCTED UPON THE FOLLOWING DATA:

MONTH	LIA	PORT	DIF
84	-0.0049200002	-0.0091439467	-0.0042239465
85	0.0073779998	0.0500006266	0.0426226258
86	0.0064139999	0.0290627852	0.0226487853
87	-0.0369299985	-0.0087748254	0.0281551741
88	-0.0717199966	-0.0408916809	0.0308283158
89	-0.0172600001	-0.0077189291	0.0095410710
90	0.0247970000	0.0432149470	0.0184179470
91	-0.0405899994	-0.0093635768	0.0312264226
92	-0.0243800003	0.0198711567	0.0442511588
93	-0.0573999994	-0.0359051302	0.0214948691
94	0.0968960002	-0.1454212815	-0.2423172891
95	-0.0000500000	-0.0123835430	-0.0123335430
96	0.0181620009	0.0374896154	0.0193276145
97	0.0774770007	0.0865747333	0.0090977326
98	0.0179789998	0.0243982524	0.0064192526
99	0.0464700013	-0.0064554564	0.0400145464
100	0.0297400001	-0.0108487122	0.0188912880
101	0.0134399999	0.0099289045	0.0233689044
102	0.0576109998	0.0509947352	-0.0066162646
103	0.0356100015	-0.0211411919	0.0144688096
104	0.0013400000	-0.0009915107	0.0003484893
105	0.0458530001	0.0319963023	-0.0138566978
106	0.0231340006	0.0141323283	-0.0090016723
107	0.0217243396	-0.0049838545	-0.0267081931

TURNOVER = 0.2540976 %

VARIANCE AT OLD WEIGHTS = 14.01026
VARIANCE AT NEW WEIGHTS = 14.12339
DELTA = -0.8010368 %

*** BUY ***

*** WEIGHTS *** OLD	NEW	DELTA	SPAN SENSIT	SIC CODE	SYMBOL IDC	TICK	SECURITY NAME
2.847	3.000	0.153	2.124	65	KOG	KOG	KOGER PPTYS INC
2.680	2.944	0.265	2.508	67	MTRV	MT	MEDITRUST SH BEN INT

*** SELL ***

*** WEIGHTS *** OLD	NEW	DELTA	SPAN SENSIT	SIC CODE	SYMBOL IDC	TICK	SECURITY NAME

*** INDUSTRY WEIGHTINGS ***

CODE	INDUSTRY	WEIGHT
1	AGRICULTURAL PRODUCTION-CROPS	2.20 %
8	FORESTRY	2.81 %
12	BITUMINOUS COAL & LIGNITE MIN.	2.88 %
13	OIL & GAS EXTRACTION	0.50 %
20	FOOD KINDRED PRODUCTS	3.60 %
23	APP. & OTH. FIN. PROD. MFFAOSM	0.57 %
25	FURNITURE AND FIXTURES	1.10 %
27	PRINTING PUBLISHING AND A.P.	3.29 %
29	PETROLEUM REFIN. & REL. PROD.	3.54 %
30	RUBBER AND MISC. PLAST. PROD.	3.02 %
32	STONE CLAY GLASS & CONC. PROD.	1.22 %
35	MACHINERY EXCEPT ELECTRICAL	5.18 %
36	ELE. AND ELE. MACH.	3.05 %
37	TRANSPORTATIONS EQUIPMENT	2.33 %
38	MEAS. ANAL. & CONT. INST. ETC.	6.08 %
45	TRANSPORTATION BY AIR	2.63 %
48	COMMUNICATION	4.37 %
49	ELECTRIC GAS AND SANIT. SERV.	16.33 %
51	WHOLESALE TRADE-NONDUR. GOODS	2.88 %
52	BUILDING MAT. HARD. GAR. SUPP.	1.83 %
60	BANKING	4.63 %
61	CRED. AGEN. OTH. THAN BANKS.	2.63 %
65	REAL ESTATE	3.00 %
67	HOLD. AND OTHER INV. COMP.	13.35 %
73	BUSINESS SERVICES	3.77 %
75	AUTO. REPAIR SERV. AND GAR.	0.99 %
80	HEALTH SERVICES	2.25 %
	TOTAL =	100.00 %

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WHAT IS CLAIMED IS:

1. A method of correlating a future asset return of a portfolio to future financial liabilities variable over time, comprising the steps of:

(a) determining future payments needed over time to fulfill said future financial liabilities;

(b) selecting a standard index having a standard asset return over time for meeting said future payments; and

(c) analyzing a plurality of assets for identifying selected ones of said assets for providing optimum correlation of the future return of said selected assets to said standard asset return, said optimum correlation achieved by calculating a minimum standard deviation for the difference between the future returns of said plurality of selected assets and said standard asset return, ranking said selected assets from smallest to largest covariance, making an iterative change in weights of said selected assets, reordering the rank of said selected assets and continuing said iterative weight and rank change of said selected assets until the covariance converges to an optimal solution.

2. The method as defined in Claim 1 wherein said future financial liabilities comprises a pension plan.

3. The method as defined in Claim 1 wherein said plurality of assets exhibit sensitivity to the same parameter as said future financial liabilities for which said time dependent optimum correlation is determined.

4. A system for correlating a future asset return of a portfolio to future financial liabilities variable over time, comprising:

means for determining future payments needed over time to fulfill said future financial liabilities;

means for selecting a standard having a standard asset return over time to meet said future payments; and

means for analyzing a plurality of assets for identifying selected ones of said assets for providing optimum correlation of the future return of said selected assets to said standard asset return, said optimum correlation achieved by means for calculating a minimum standard deviation for the difference between the future returns of said plurality of assets and said selected standard asset return, said calculating means further ranking said selected assets from smallest to largest covariance, making an iterative change in weights of said selected assets, reordering the rank of said selected assets and continuing said iterative weight and rank change of said selected assets until the covariance converges.

5. The system as defined in Claim 4 wherein said future financial liabilities comprise insurance liabilities and pension plan liabilities.

6. The method as defined in Claim 4 wherein a computer performs the functional operations.

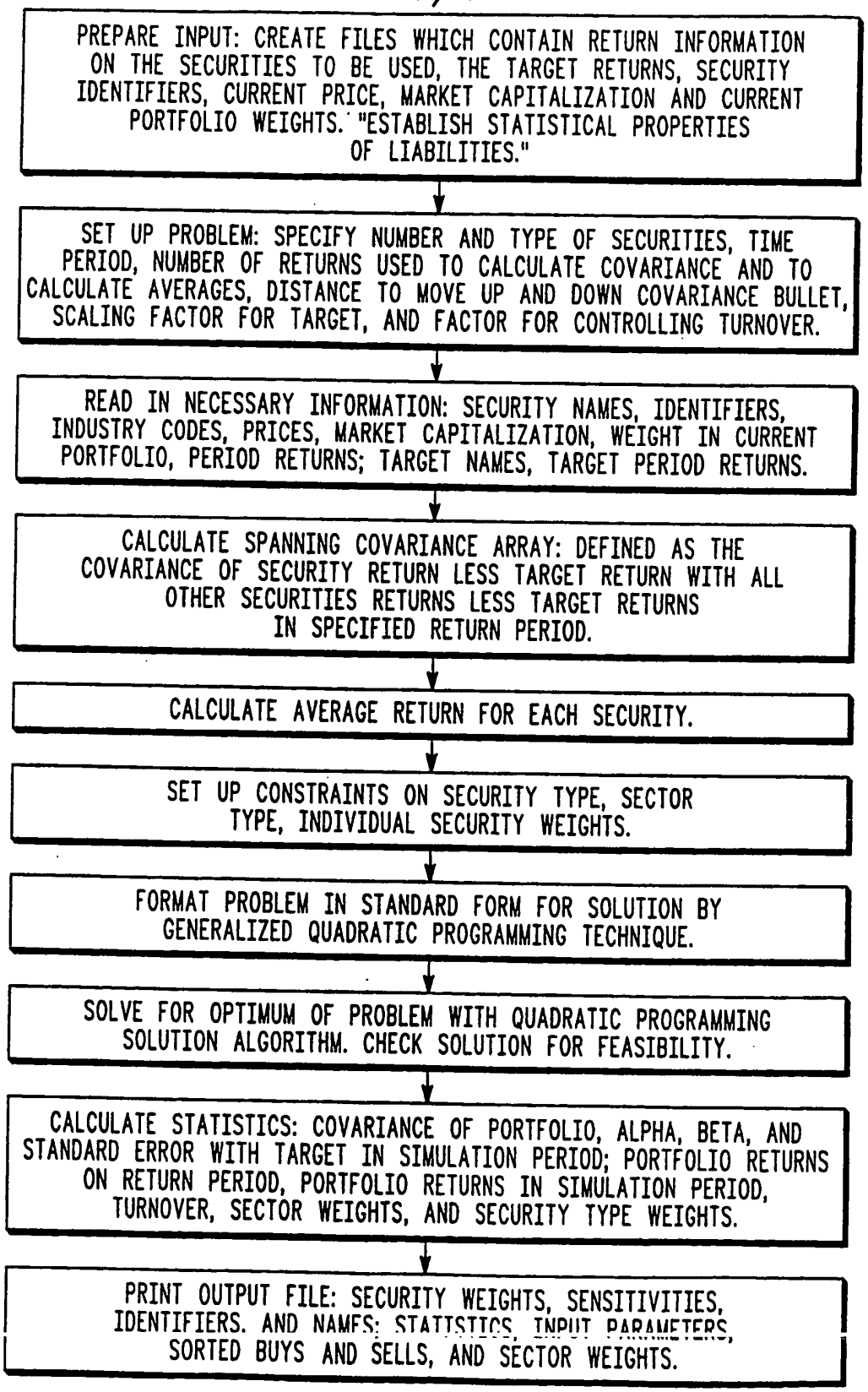

PREPARE INPUT: CREATE FILES WHICH CONTAIN RETURN INFORMATION ON THE SECURITIES TO BE USED, THE TARGET RETURNS, SECURITY IDENTIFIERS, CURRENT PRICE, MARKET CAPITALIZATION AND CURRENT PORTFOLIO WEIGHTS. "ESTABLISH STATISTICAL PROPERTIES OF LIABILITIES."
SET UP PROBLEM: SPECIFY NUMBER AND TYPE OF SECURITIES, TIME PERIOD, NUMBER OF RETURNS USED TO CALCULATE COVARIANCE AND TO CALCULATE AVERAGES, DISTANCE TO MOVE UP AND DOWN COVARIANCE BULLET, SCALING FACTOR FOR TARGET, AND FACTOR FOR CONTROLLING TURNOVER.
READ IN NECESSARY INFORMATION: SECURITY NAMES, IDENTIFIERS, INDUSTRY CODES, PRICES, MARKET CAPITALIZATION, WEIGHT IN CURRENT PORTFOLIO, PERIOD RETURNS; TARGET NAMES, TARGET PERIOD RETURNS.
CALCULATE SPANNING COVARIANCE ARRAY: DEFINED AS THE COVARIANCE OF SECURITY RETURN LESS TARGET RETURN WITH ALL OTHER SECURITIES RETURNS LESS TARGET RETURNS IN SPECIFIED RETURN PERIOD.
CALCULATE AVERAGE RETURN FOR EACH SECURITY.
SET UP CONSTRAINTS ON SECURITY TYPE, SECTOR TYPE, INDIVIDUAL SECURITY WEIGHTS.
FORMAT PROBLEM IN STANDARD FORM FOR SOLUTION BY GENERALIZED QUADRATIC PROGRAMMING TECHNIQUE.
SOLVE FOR OPTIMUM OF PROBLEM WITH QUADRATIC PROGRAMMING SOLUTION ALGORITHM. CHECK SOLUTION FOR FEASIBILITY.
CALCULATE STATISTICS: COVARIANCE OF PORTFOLIO, ALPHA, BETA, AND STANDARD ERROR WITH TARGET IN SIMULATION PERIOD; PORTFOLIO RETURNS ON RETURN PERIOD, PORTFOLIO RETURNS IN SIMULATION PERIOD, TURNOVER, SECTOR WEIGHTS, AND SECURITY TYPE WEIGHTS.
PRINT OUTPUT FILE: SECURITY WEIGHTS, SENSITIVITIES, IDENTIFIERS. AND NAMES; STATISTICS, INPUT PARAMETERS, SORTED BUYS AND SELLS, AND SECTOR WEIGHTS.

Fig. 1a

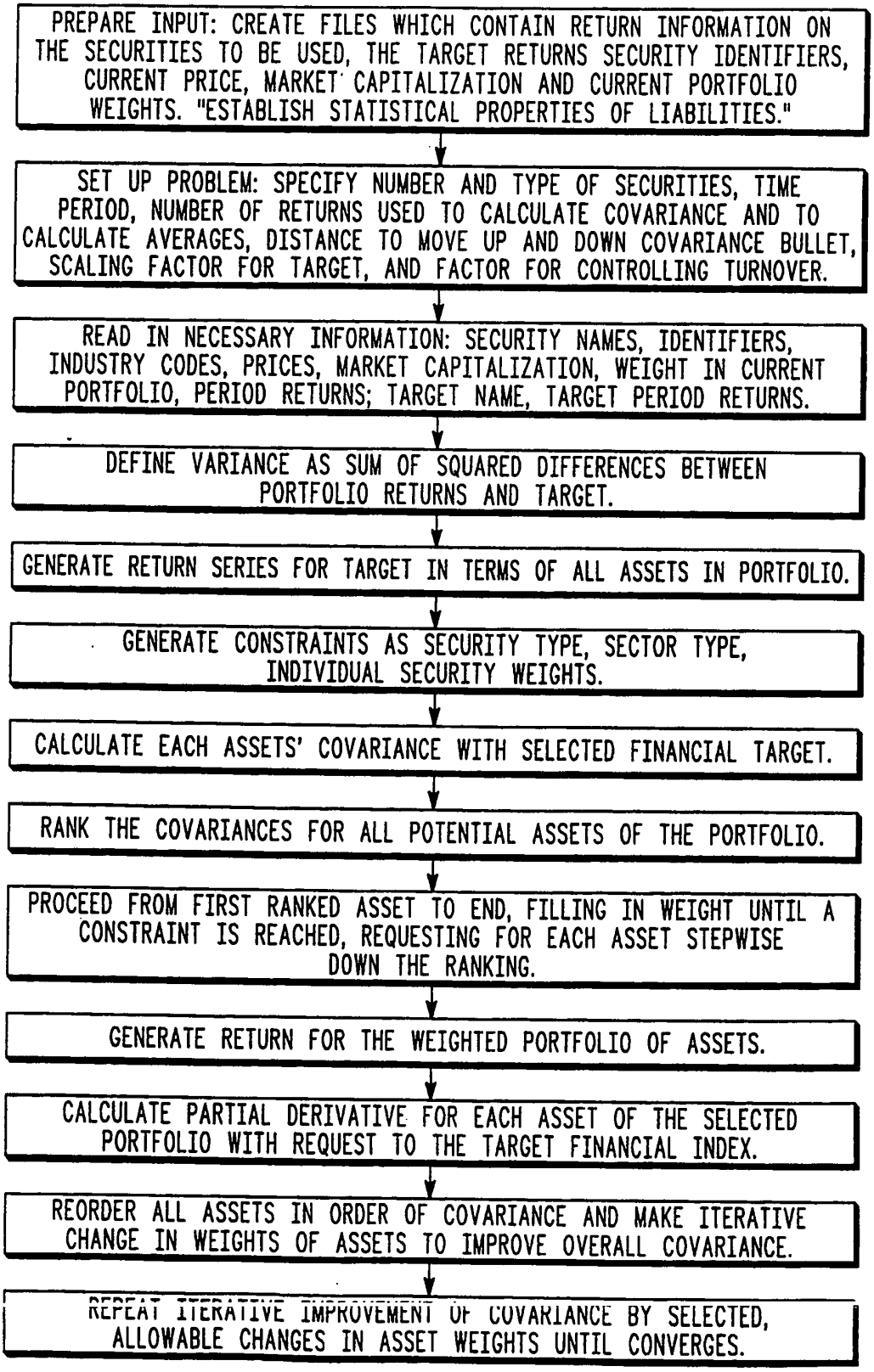

PREPARE INPUT: CREATE FILES WHICH CONTAIN RETURN INFORMATION ON THE SECURITIES TO BE USED, THE TARGET RETURNS SECURITY IDENTIFIERS, CURRENT PRICE, MARKET CAPITALIZATION AND CURRENT PORTFOLIO WEIGHTS. "ESTABLISH STATISTICAL PROPERTIES OF LIABILITIES."
SET UP PROBLEM: SPECIFY NUMBER AND TYPE OF SECURITIES, TIME PERIOD, NUMBER OF RETURNS USED TO CALCULATE COVARIANCE AND TO CALCULATE AVERAGES, DISTANCE TO MOVE UP AND DOWN COVARIANCE BULLET, SCALING FACTOR FOR TARGET, AND FACTOR FOR CONTROLLING TURNOVER.
READ IN NECESSARY INFORMATION: SECURITY NAMES, IDENTIFIERS, INDUSTRY CODES, PRICES, MARKET CAPITALIZATION, WEIGHT IN CURRENT PORTFOLIO, PERIOD RETURNS; TARGET NAME, TARGET PERIOD RETURNS.
DEFINE VARIANCE AS SUM OF SQUARED DIFFERENCES BETWEEN PORTFOLIO RETURNS AND TARGET.
GENERATE RETURN SERIES FOR TARGET IN TERMS OF ALL ASSETS IN PORTFOLIO.
GENERATE CONSTRAINTS AS SECURITY TYPE, SECTOR TYPE, INDIVIDUAL SECURITY WEIGHTS.
CALCULATE EACH ASSETS' COVARIANCE WITH SELECTED FINANCIAL TARGET.
RANK THE COVARIANCES FOR ALL POTENTIAL ASSETS OF THE PORTFOLIO.
PROCEED FROM FIRST RANKED ASSET TO END, FILLING IN WEIGHT UNTIL A CONSTRAINT IS REACHED, REQUESTING FOR EACH ASSET STEPWISE DOWN THE RANKING.
GENERATE RETURN FOR THE WEIGHTED PORTFOLIO OF ASSETS.
CALCULATE PARTIAL DERIVATIVE FOR EACH ASSET OF THE SELECTED PORTFOLIO WITH REQUEST TO THE TARGET FINANCIAL INDEX.
REORDER ALL ASSETS IN ORDER OF COVARIANCE AND MAKE ITERATIVE CHANGE IN WEIGHTS OF ASSETS TO IMPROVE OVERALL COVARIANCE.
REPEAT ITERATIVE IMPROVEMENT OF COVARIANCE BY SELECTED, ALLOWABLE CHANGES IN ASSET WEIGHTS UNTIL CONVERGES.

Fig. 1b

Fig. 2a

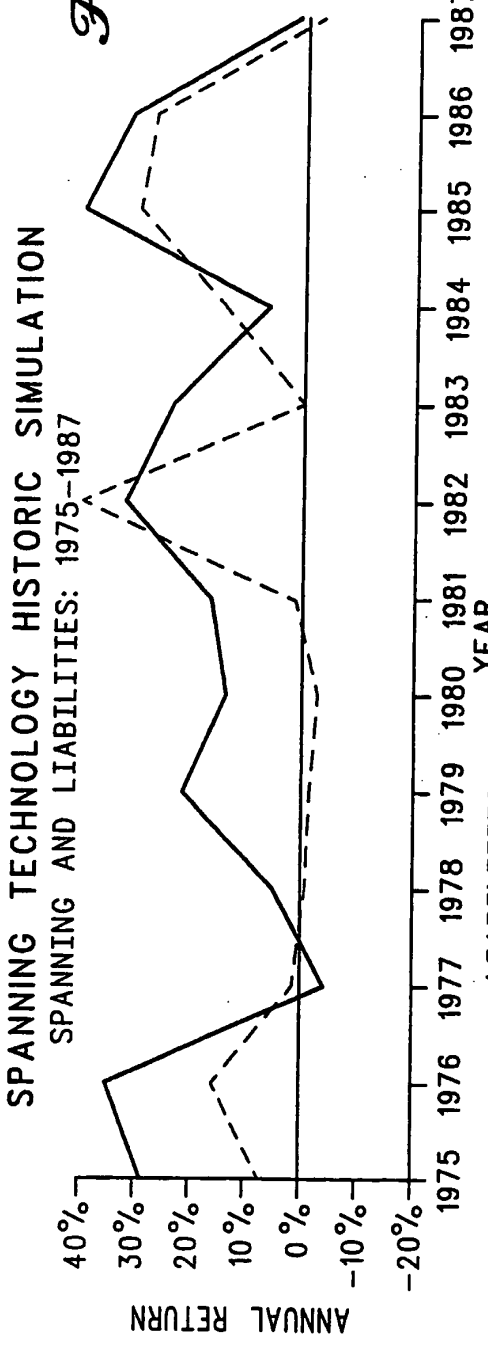

SPANNING TECHNOLOGY HISTORIC SIMULATION
SPANNING AND LIABILITIES: 1975–1987
ANNUAL RETURN
40%
30%
20%
10%
0%
-10%
-20%
1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987
YEAR
---LIABILITIES
—SPANNING PORTFOLIO

Fig. 2b

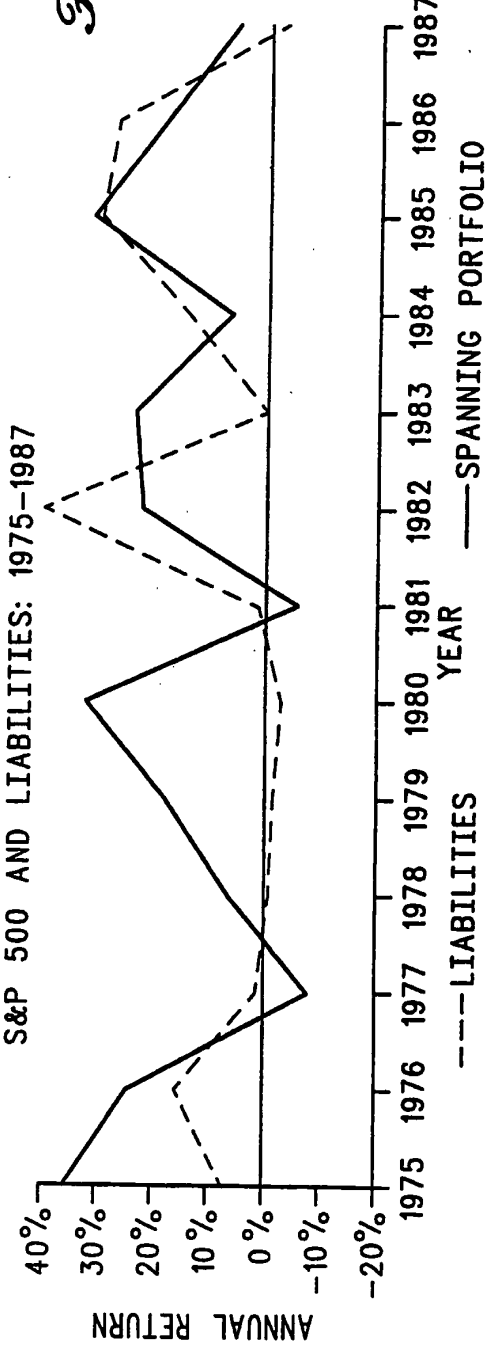

S&P 500 AND LIABILITIES: 1975–1987
ANNUAL RETURN
40%
30%
20%
10%
0%
-10%
-20%
1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987
YEAR
---LIABILITIES
—SPANNING PORTFOLIO

Fig. 3a

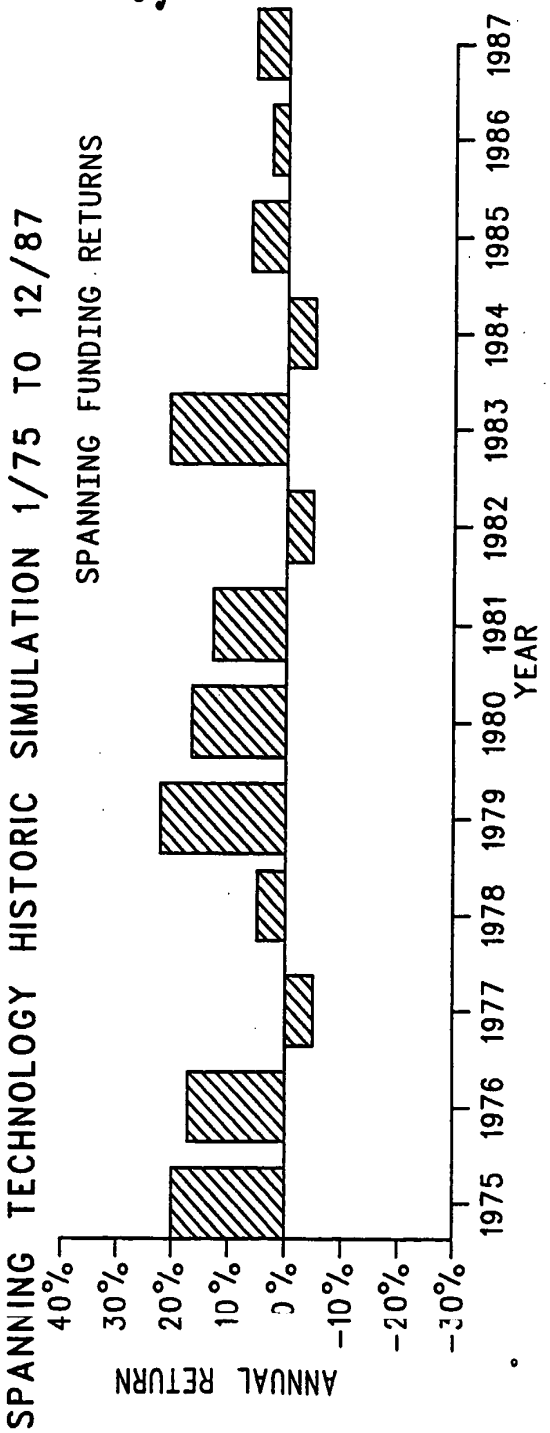
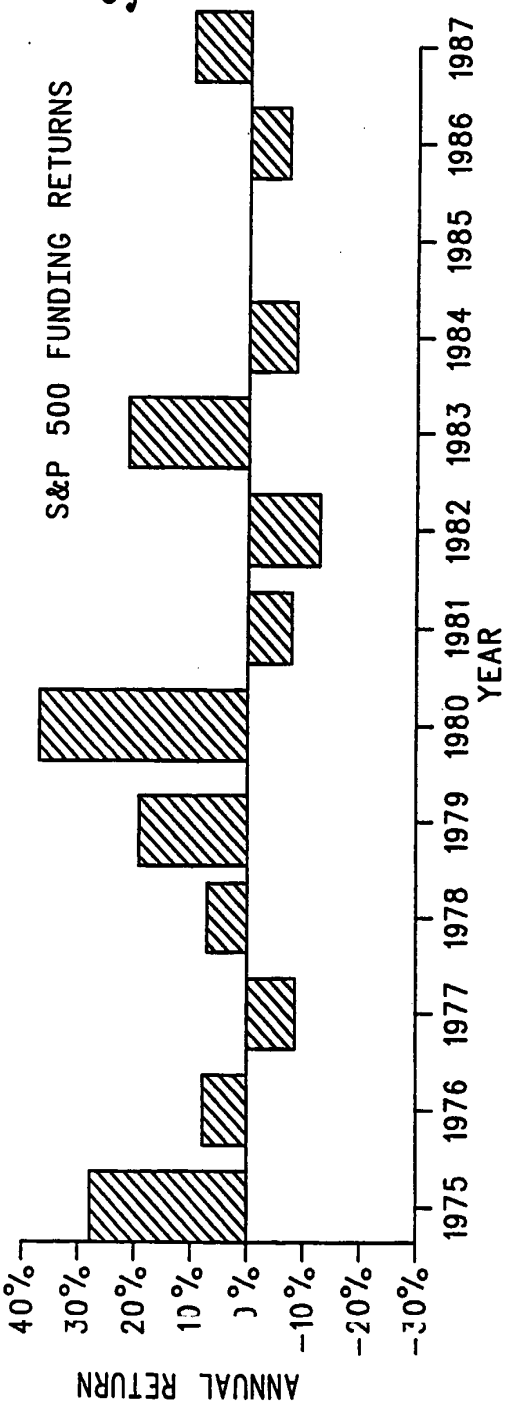

SPANNING TECHNOLOGY HISTORIC SIMULATION 1/75 TO 12/87
SPANNING FUNDING RETURNS
ANNUAL RETURN
40%
30%
20%
10%
0%
-10%
-20%
-30%
1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987
YEAR

Fig. 3b


S&P 500 FUNDING RETURNS
ANNUAL RETURN
40%
30%
20%
10%
0%
-10%
-20%
-30%
1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987
YEAR

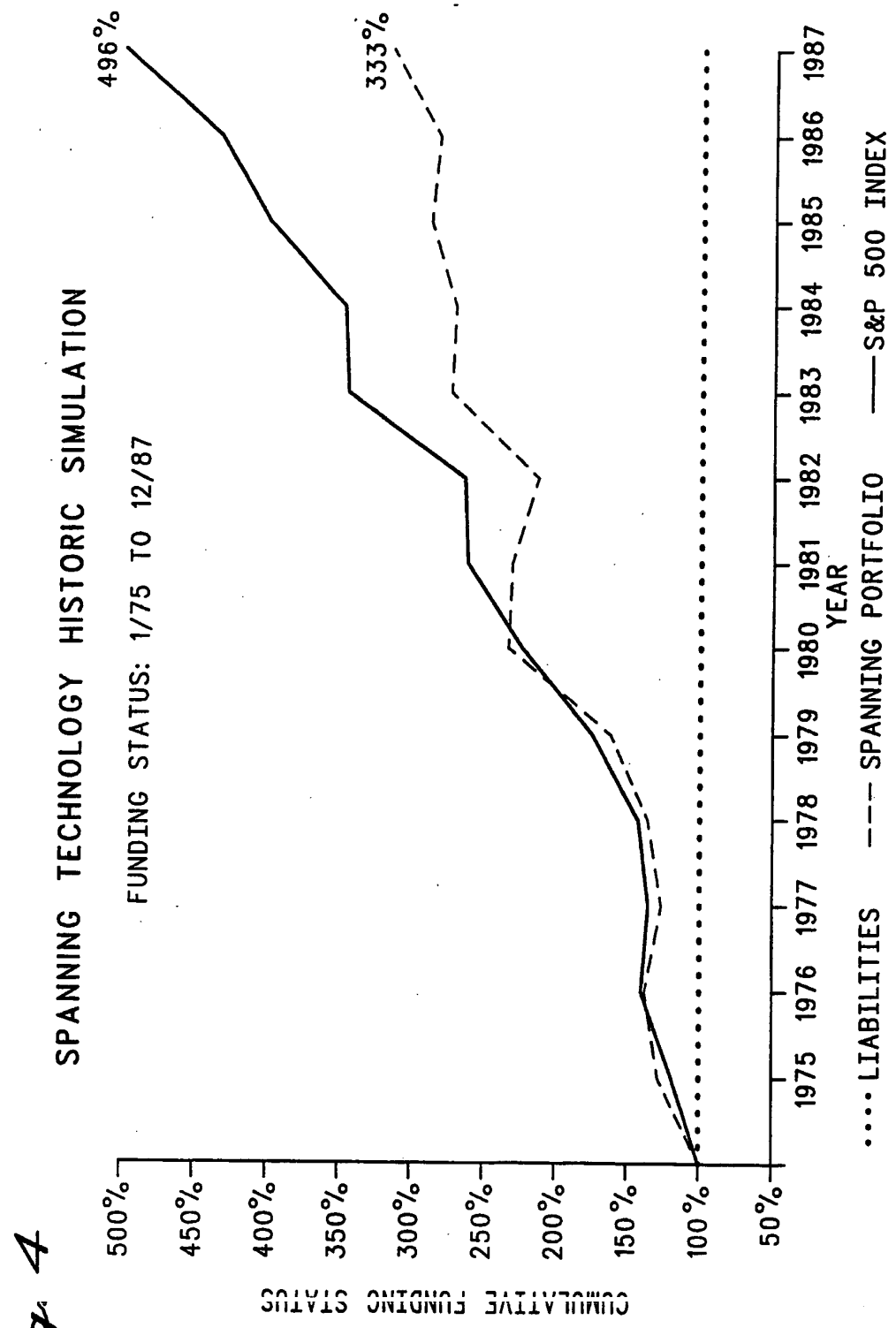

SPANNING TECHNOLOGY HISTORIC SIMULATION
FUNDING STATUS: 1/75 TO 12/87
496%
333%
CUMULATIVE FUNDING STATUS
500%
450%
400%
350%
300%
250%
200%
150%
100%
50%
1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987
YEAR
.... LIABILITIES
---- SPANNING PORTFOLIO
—— S&P 500 INDEX

Fig. 4

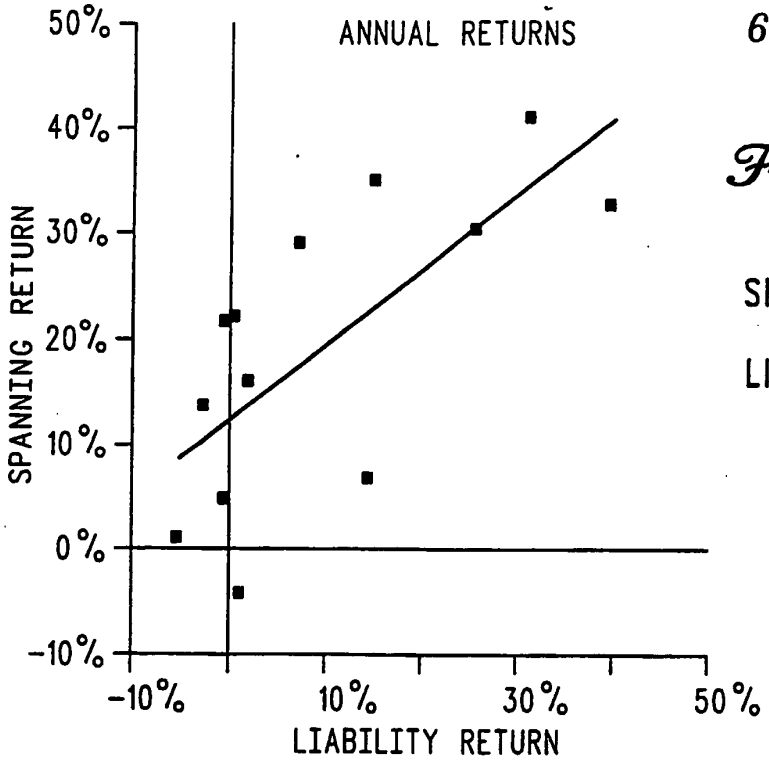


Fig. 5a

SPANNERS VS. LIABILITIY

LIABILITY BETA = 0.686
CORRELATION = 69.7%

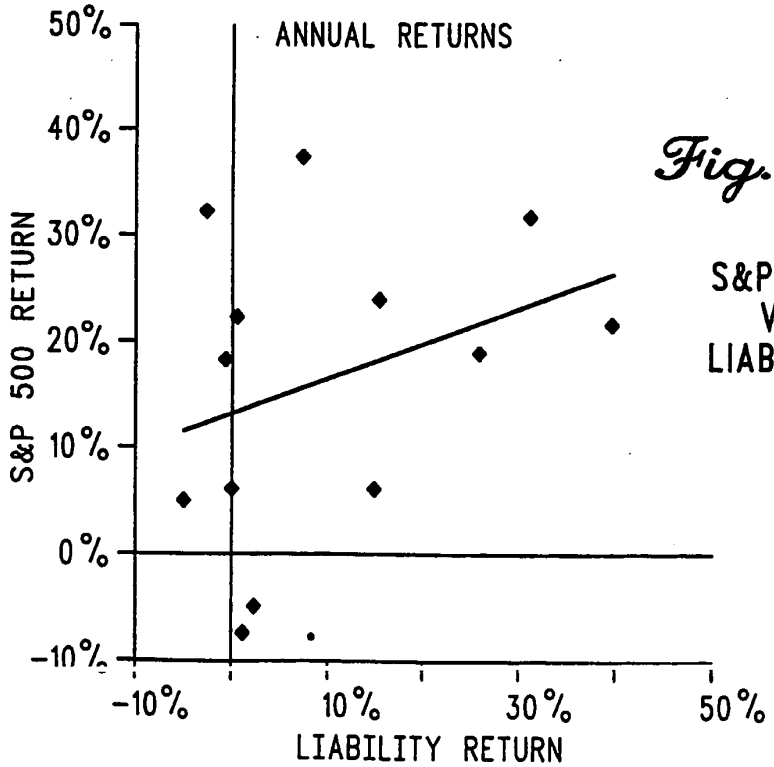
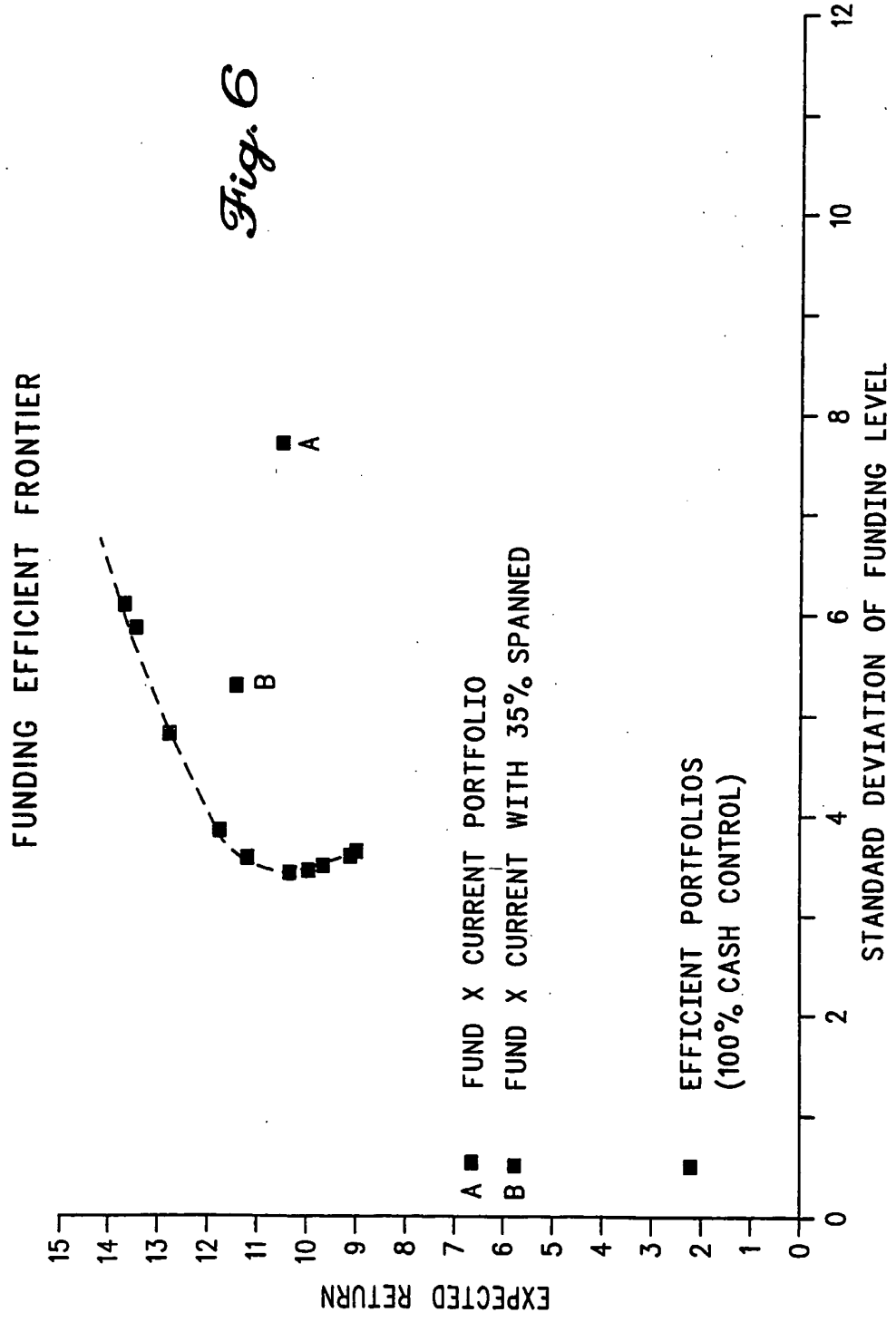


Fig. 5b

S&P 500 VS. LIABILITIY

LIABILITY BETA = 0.327
CORRELATION = 33.3%

Fig. 6


FUNDING EFFICIENT FRONTIER
A
B
A ■ FUND X CURRENT PORTFOLIO
B ■ FUND X CURRENT WITH 35% SPANNED
■ EFFICIENT PORTFOLIOS (100% CASH CONTROL)
EXPECTED RETURN
STANDARD DEVIATION OF FUNDING LEVEL
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
0
2
4
6
8
10
12

INTERNATIONAL SEARCH REPORT

International Application No PCT/US90/04328

I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC(5): G06F 15/21
US CL.: 364/401, 408

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System [5]	Classification Symbols
US	364/401, 408

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [6]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category [15]	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
A	US, A, 4,642,768 (ROBERTS) 10 February 1987	1-6
A	US, A, 4,648,038 (ROBERTS et al.) 03 Marhc 1987	1-6
A	US, A, 4,722,055 (ROBERTS) 26 January 1988	1-6
A	US, A, 4,739,478 (ROBERTS et al.) 19 April 1988	1-6
A	US, A, 4,750,121 (HALLEY et al.) 07 June 1988	1-6
A	US, A, 4,752,877 (ROBERTS et al.) 21 June 1988	1-6
A	US, A, 4,839,804 (ROBERTS et al.) 13 June 1989	1-6
A,P	US, A, 4,933,842 (DURBIN et al.) 12 June 1990	1-6
A	Haugen, "Modern Investment Theory" published 1985 by Prentice-Hall (New Jersey), Chapters 6-8.	1-6

* Special categories of cited documents: [19]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
20 NOVEMBER 1990	25 JAN 1991
International Searching Authority [1]	Signature of Authorized Officer [20]
ISA/US	for Linda Rolemann DAVID HUNTLEY